SALMONID HABITAT LIMITING FACTORS ANALYSIS

CHAMBERS-CLOVER CREEK WATERSHED

(Including Sequalitchew Creek and Independent Tributaries)

WATER RESOURCE INVENTORY AREA

12

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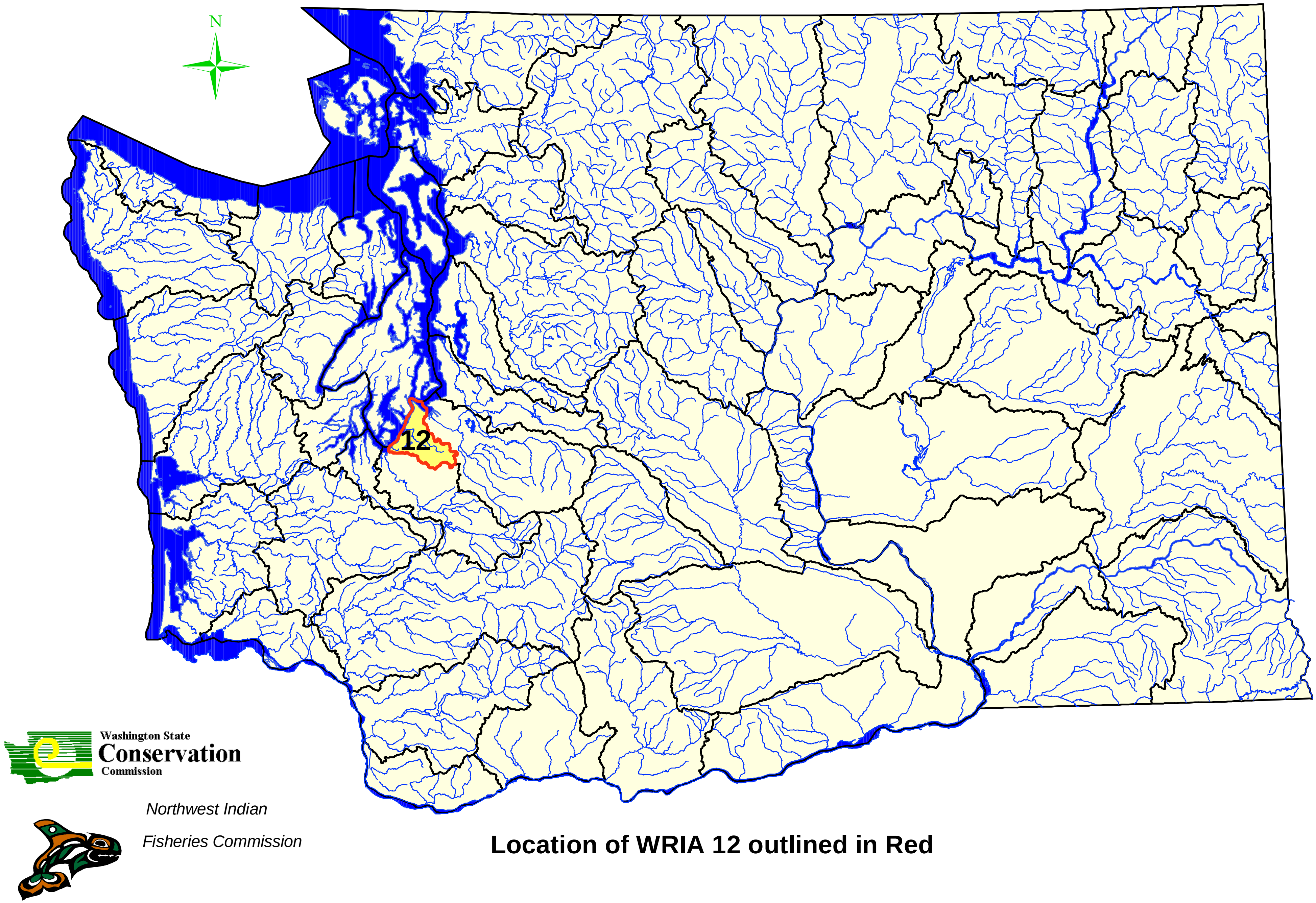


Location of WRIA 12 outlined in Red

EXECUTIVE SUMMARY

Section 10 of Engrossed Substitute House Bill 2496 (Salmon Recovery Act of 1998), directs the Washington State Conservation Commission, in consultation with local government and treaty tribes to invite private, federal, state, tribal, and local government personnel with appropriate expertise to convene as a Technical Advisory Group (TAG). The purpose of the TAG is to identify limiting factors for salmonids. Limiting factors are defined as "conditions that limit the ability of habitat to fully sustain populations of salmon, including all species of the family Salmonidae." It is important to note that the charge to the Conservation Commission in ESHB 2496 does not constitute a full limiting factors analysis. A full habitat limiting factors analysis would require extensive additional scientific studies for each of the subwatersheds in the Clover/Chambers and Sequalitchew watersheds (Water Resource Inventory Area – WRIA – 12). Analysis of hatchery, hydro, and harvest impacts would also be inherent components of a comprehensive limiting factors analysis; these elements are not addressed in this report, but will be considered in other forums.

INTRODUCTION

The quantity and quality of aquatic habitat present in any stream, river, lake, or estuary is a reflection of the existing physical habitat characteristics (e.g. depth, structure, gradient, etc) as well as the water quality (e.g. temperature and suspended sediment load). There are a number of processes that create and maintain these features of aquatic habitat. In general, the key processes regulating the condition of aquatic habitats are the delivery and routing of water (and its associated constituents such as nutrients), sediment, and large woody debris (LWD). These processes operate over the terrestrial and aquatic landscape. For example, climatic conditions operating over very large scales can drive many habitat forming processes while the position of a fish in the stream channel can depend upon delivery of wood from forest adjacent to the stream. In addition, ecological processes operate at various spatial and temporal scales and have components that are lateral (e.g., floodplain), longitudinal (e.g., landslides in upstream areas) and vertical (e.g., riparian forest).

The effect of each process on habitat characteristics is a function of variations in local geomorphology, climatic gradients, spatial and temporal scales of natural disturbance, and terrestrial and aquatic vegetation. For example, wood is a more critical component of stream habitat than in lakes, where it is primarily an element of littoral habitats. In stream systems, the routing of water is primarily via the stream channel and subsurface routes whereas in lakes, water is routed by circulation patterns resulting from inflow, outflow and climatic conditions.

Human activities degrade and eliminate aquatic habitats by altering the key natural processes described above. This can occur by disrupting the lateral, longitudinal, and vertical connections of system components as well as altering spatial and temporal variability of the components. In addition, humans have further altered habitats by creating new processes such as the actions of exotic species. The following sections identify and describe the major alterations of aquatic habitat that have occurred and why they have occurred. These alterations are discussed as limiting factors.

Discussion of Habitat Limiting Factor Elements

Fish Passage Barriers

Salmon are limited to certain spawning and rearing locations by natural features of the landscape. These features include channel gradient and the presence of physical features of the landscape (e.g. logjams). Flow can affect the ability of some landscape features to function as barriers. For example, some waterfalls may be impassable at low flows, but then become passable at higher flows. In some cases, flows themselves can present a barrier, such as when extreme low flows occur in some channels; at higher flows fish are not blocked. Flow conditions may also allow accessibility to some anadromous salmonid species, while precluding access to others.

Throughout Washington, barriers have been constructed that have restricted or prevented juvenile and adult fish from gaining access to formerly accessible habitat. The most obvious of these barriers are dams and diversions with no passage facilities that prevent adult salmon from accessing historically used spawning grounds. Culverts are often full or partial fish passage barriers; delayed fish passage during certain flow conditions can be equally as detrimental as a total fish passage barrier. In addition, in recent years it has become increasingly clear that we have also constructed barriers that prevent juveniles from accessing rearing habitat. For example, dikes and levees have blocked off historically accessible side-channel rearing areas, and poorly designed culverts in streams have impacted the ability of juvenile salmonids to move upstream into rearing areas.

Functions of Floodplains

Floodplains are portions of a watershed that are periodically flooded by the lateral overflow of rivers and streams. In general, most floodplain areas are located in lowland areas of river basins and are associated with higher order streams. Floodplains are typically structurally complex, and are characterized by a great deal of lateral, aquatic connectivity by way of distributaries, sloughs, backwaters, side-channels, oxbows, and lakes. Often, floodplain channels can be highly braided (multiple parallel channels).

Properly functioning floodplains provide critical habitat. Aquatic habitats in floodplain areas can be very important for Chinook and Coho salmon juveniles that often over-winter and seek refuge from high flows in the sloughs and backwaters of floodplains. Floodplains also help dissipate water energy during floods by allowing water to escape the channel and inundate the terrestrial landscape, lessening the impact of floods on incubating salmon eggs. Floodplains also provide coarse beds of alluvial sediments through which subsurface flow passes. This acts as a filter of nutrients and other chemicals to maintain high water quality. Floodplains also provide an area for sediment deposition and storage, particularly for fine sediment, outside of the river channel, reducing the effects of sediment deposition and instability in the river channel.

Impairment of Floodplains by Human Activities

Large portions of the floodplains of many Washington rivers, especially those in the western part of the state, have been converted to urban and agricultural land uses. Many of the urban areas of the state are located in lowland floodplains, while land used for agricultural purposes is often located in floodplains because of the flat topography and rich soils deposited by the flooding rivers.

There are two major types of human impacts to floodplain functions. First, channels are disconnected from their floodplain. This occurs both laterally as a result of the construction of dikes and levees, which often occur simultaneously with the construction of roads, and longitudinally as a result of the construction of road crossings. This has: 1) eliminated off-channel habitats such as sloughs and side channels; 2) increased flow velocity during flood events due to the constriction of the channel; 3) reduced subsurface flows and groundwater contribution to the stream; and 4) simplified channels since LWD is lost and channels are often straightened when levees are constructed. Channels can also become disconnected from their floodplains as a result of down-cutting and incision of the channel from losses of LWD, decreased sediment supplies, and increased high flow events.

The second major type of impact is loss of natural riparian and upland vegetation. The natural riparian and terrestrial vegetation in most Pacific Northwest floodplain areas was historically coniferous forest, although portions of WRIA 12 are thought to have exhibited substantial oak prairie hardwood forest as well. Conversion of these forested areas to impervious surfaces, sparse deciduous growth, meadows, grasslands, and farmed fields has occurred as floodplains have been converted to urban and agricultural uses. Riparian forests are typically reduced or eliminated as levees and dikes are constructed. Loss of vegetation on the floodplain reduces shading of water in floodplain channels, eliminates LWD contribution, reduces filtering of sediments, nutrients and toxics, and results in increased water energy during flood flows.

Elimination of off-channel habitats results in the loss of important habitats for juvenile salmonids. Side channels, sloughs and backwaters that are isolated from flooding impacts historically functioned as prime spawning habitat for chum, pink, and Coho, and rearing and over-wintering habitat for Chinook and Coho juveniles. The loss of LWD from channels reduces the amount of rearing habitat available for Chinook juveniles. Disconnection of the stream channels from their floodplain due to levee and dike construction increases water velocities, which in turn increases scour of the streambed. Salmon that spawn in these areas may have reduced egg to fry survival due to the scour. Removal of mature native vegetation from riparian zones can increase stream temperatures in channels, which can stress both adult and juvenile salmon. Sufficiently high temperatures can increase mortality.

Streambed Sediment

The sediments present in an ecologically healthy stream channel are naturally dynamic and are a function of a number of processes that input, store, and transport the materials. Processes naturally vary spatially and temporally and depend upon a number of features of the landscape such as stream order, gradient, stream size, basin size, geomorphic context, and hydrological regime. In forested mountain basins, sediment enters stream channels from natural mass wasting events (e.g. landslides and debris flows), channel bank erosion (particularly in glacial deposits), surface erosion, and soil creep. Natural input of sediment to stream channels in these types of basins occurs periodically during extreme climatic events such as floods (increasing erosion) and mass wasting. In lowland, or higher order streams, lateral erosion is the major natural sediment source. Inputs of sediment in these basins tend to be steadier in geologic time.

Once sediment enters a stream channel it can be stored or transported depending upon particle size, stream gradient, hydrological conditions, availability of storage sites, and channel type or morphology. Finer sediments tend to be transported through the system as wash load or suspended load, and have relatively little effect on channel morphology. Coarser sediments (>2 mm diameter) tend to travel as bedload, and can have larger effects on channel morphology as they move downstream, depositing through the channel network.

Some parts of the channel network are more effective at storing sediment, while other parts of the network are more effective at transporting material. There are also strong temporal components to sediment storage and transport, such as seasonal floods, which tend to transport more material. One channel segment may function as a storage site during one time of year and a transport reach at other times. In general, the coarsest sediments are found in upper watersheds while the finest materials are found in the lower reaches of a watershed. Storage sites include various types of channel bars and floodplain areas, and are often associated with LWD.

Effects of Human Actions on Sediment Processes

Changes in the supply, transport, and storage of sediments can occur as the direct result of human activities. Human actions can result in increases or decreases in the supply of sediments to a stream. Increases in sediment deposition in the channel result from increased erosion due to land use practices or isolation of the channel from the floodplain (due to presence of dikes or roads), which eliminate important off-channel storage areas for sediment and increase the sediment load beyond the transport capacity of the stream. In addition, actions that destabilize the landscape in high slope areas such as logging or road construction increase the frequency and severity of mass wasting events. Finally, increases in the frequency and magnitude of flood flows, and/or loss of floodplain vegetation, increase erosion. Increased erosion fills pools and aggrades the channel, resulting in reduced habitat complexity and reduced rearing capacity for some salmonids. Increased total sediment supply to a channel increases the proportion of fine sediments in the bed, which can reduce the survival of incubating eggs in the gravel and change benthic invertebrate production.

Decreases in sediment supply occur in some streams, primarily as a result of disconnecting the channel from the floodplain. Dams typically block the supply of sediment from upper watershed areas while levees typically isolate the stream from natural upland sources of sediment. In addition, gravels are removed from streambeds to increase flow capacity (dredging) or for mineral extraction purposes. Reduction in sediment supply can alter the streambed composition, which can coarsen the substrate and reduce the amount of gravel substrate suitable for spawning.

In addition to affecting sediment supply, human activities can also affect the storage and movement of sediment in a stream. An understanding of how sediment moves through a system is important for determining where sediment will have the greatest effect on salmonid habitat and for determining which areas will have the greatest likelihood of altering habitats. In general, transport of sediment changes as a result of gradient, hydrology changes (water removal, increased peak flows, or altered timing and magnitude of peak flows), and isolation of the channel from its floodplain. Larger and more frequent flood flows move larger and greater amounts of material more frequently. This can increase bed scour and bank erosion, alter channel morphology, and ultimately degrade the quality of spawning and rearing habitat. Unstable channels become very dynamic and unpredictable compared to the relatively stable channels characteristic of undeveloped areas. Additional reductions in the levels of instream LWD can greatly alter sediment storage and processing patterns, resulting in increased levels of fines in gravels and reduced organic material storage and nutrient cycling.

Riparian Zone Functions

Stream riparian zones include the area of living and dead vegetative material adjacent to a stream. They extend from the edge of the ordinary high water mark of the wetted channel, upland to a point where the zone ceases to have an influence on the stream channel. Riparian forest characteristics in ecologically healthy watersheds are strongly influenced by climate, channel geomorphology, and where the channel is located in the drainage network. Large-scale natural disturbances (fires, severe windstorms, and debris flows) can dramatically alter riparian characteristics. These natural events are typically infrequent, with recovery to healthy riparian conditions for extended periods of time following the disturbance event. The width of the riparian zone and the extent of the riparian zone's influence on the stream are strongly related to stream size and drainage basin morphology. In a basin un-impacted by humans, the riparian zone would exist as a mosaic of tree stands of different acreage, ages (e.g. sizes), and species.

Riparian zone functions include providing hydraulic diversity, adding structural complexity, buffering the energy of runoff events and erosive forces, moderating temperatures, protecting water quality, and providing a source of food and nutrients. They are especially important as the LWD source for streams. LWD directly influences several habitat attributes important to anadromous species. In particular, LWD helps form and maintain the pool structure in streams, and provides a mechanism for sediment and organics sorting and storage upstream and adjacent to LWD formations. Pools provide a refuge from predators and high-flow events for juvenile salmon, especially Coho that rear for extended periods in streams.

Effects of Human Activities on Riparian Zones

Riparian zones are impacted by all types of land use practices. Riparian functions are impaired by direct removal of riparian vegetation; by roads and dikes located adjacent to the stream channel; by road crossings, agricultural/livestock crossings, and timber yarding corridors that cross the stream channel; by unrestricted livestock grazing in the riparian zone; and by development encroachment into the riparian corridor. Further, riparian vegetation species composition can be dramatically altered when native trees are replaced by exotic species (e.g., shrubs, reed canarygrass), and where native coniferous riparian areas are converted to deciduous tree species. Deciduous trees are typically of smaller diameter than conifers and decompose faster than conifers, so they do not persist as long in streams and are vulnerable to being washed out by lower magnitude floods. Once impacted, riparian functions can take many decades to recover as forest cover regrows, and coniferous species colonize. It may take as long as 80-120 years to restore functional LWD contribution to the channel.

Changes to riparian zones affect many attributes of stream ecosystems. For example, stream temperatures can increase due to the loss of shade, while streambanks become more prone to erosion due to elimination of the trees and their associated roots. Perhaps the most important impact of riparian alteration is a decline in the frequency, volume, and quantity of LWD due to reduced recruitment from forested areas. Loss of LWD results in a significant reduction in the complexity of stream channels including a decline of pool habitat, which reduces the number of rearing salmonids. Loss of LWD affects the amount of both over-wintering and low flow rearing habitat, as well as providing a variety of other ecological functions in the channel.

Water Quantity

The hydrologic regime of a drainage basin refers to how water is collected, moved and stored. The frequency and magnitude of floods are especially important since floods are the primary source of disturbance in streams and thus play a key role in how channels are structured and function. In ecologically healthy systems, the physical and biotic changes caused by natural disturbances are not usually sustained, and recovery is rapid to pre-disturbance levels. If the magnitude of change is sufficiently large, however, permanent impacts can occur.

Alterations in basin hydrology are caused by changes in soils, decreases in the amount of forest cover, increases in impervious surfaces, elimination of riparian and headwater wetlands, and changes in landscape context. Hydrologic impacts to stream channels occur even at low levels of development (<2% impervious area) and generally increase in severity as more of the landscape is converted to from natural forest cover to more developed land uses.

Salmonid production is typically affected by water withdrawals for irrigation, industrial, and domestic use, including water transfers between basins. Removal of water, either directly from the stream channel or from wells that are in hydraulic continuity with stream flows, reduces the amount of instream flow and useable wetted area remaining for support of adult salmonid spawning and juvenile rearing. Reduction of instream flows also typically results in increased water temperature, often to levels that impair salmonid productivity. The relationship between the useable wetted area of a stream and stream flow varies between species and life stages. For example, juvenile Coho prefer quiet water in pools for rearing, whereas juvenile steelhead prefer areas of faster water (Hiss and Lichatowich 1990). Streamflow limitations are typically greatest during the dry summer and early fall months when stream flows are lowest. In other instances stream flows may actually increase due to direct or indirect (irrigation ground water return flows) water transfers from other basins. In some instances peak flood flows may be transferred to basins that would otherwise not be affected by flood flows. These situations may increase the stream flow and useable wetted area for fish use, but the increased hydrology may cause channel bedload movement, bank erosion, loss of LWD, and other adverse habitat impacts that would not be experienced under the natural hydrology regime to which the channel is adapted.

Water Quality

Water quality affects productivity and survival of salmonids. There are several water quality parameters that affect salmonids, including water temperature, pH, dissolved oxygen, turbidity, nutrients, and toxic chemicals. Elevated water temperatures are typically associated with loss of mature riparian vegetation along the stream corridor, reduced instream flows during late summer resulting from water withdrawals, or from increased solar exposure to water impounded behind dams. Salmonids generally require a neutral pH; fish may be adversely affected by surface water with pH of 5.6 or less, and can also be adversely affected by high pH values (Spence et al. 1996). Dissolved oxygen levels are directly associated with water temperature, with saturation being higher in colder water. Turbidity refers to the presence of suspended sediment in the water column that may affect survival of eggs or fish. Storm water runoff (particularly from roads), surface erosion, and increased streambank erosion are the main contributors of turbidity. Natural stream nutrient regimes have been altered. Natural nutrient cycling has been affected by low numbers of salmon carcasses due to reduced numbers of spawners returning to streams; by removal or alteration of riparian vegetation that reduces the entry of litter fall and invertebrates; by the lack of LWD in streams that slows the loss of nutrient sources from the stream; and by storm water flows that flush available nutrients from the streams. In addition, hatchery salmon carcasses are often not returned to rivers and streams after the salmon are artificially spawned, reducing the cycling of marine-derived nutrients. Increased levels of nutrients result from storm water runoff with high levels of nitrogen and phosphorus, and from failing septics and sewage treatment plant outfalls. High nutrient levels can lower dissolved oxygen levels in a waterbody. Public health districts regularly monitor for presence of fecal coliform bacteria. Elevated fecal coliform counts that do not meet Washington State water quality standards may result in closure of marine shellfish beds to harvest, but fecal coliform bacteria are not known to affect salmonid health or survival. However, elevated fecal coliform counts may be an indicator of other salmonid habitat problems (e.g., elevated nutrient levels, low dissolved oxygen, unrestricted cattle access to streams) in the watershed. There is far less water quality monitoring for presence of toxic chemicals. Sources of toxics of concern include toxic spills (e.g., oil, paint, pesticides.), runoff from roads/parking lots, exposure of the stream or marine water to treated wood, leaching of pesticides, and leaching of heavy metals.

Estuarine Habitat

Anadromous salmonids are affected by the freshwater habitat conditions described above, but are also affected by habitat conditions in the estuary, as well as in the ocean. Worldwide, few other habitats are so valuable for fish production and yet are so imperiled as estuaries. Estuaries include the area from the uppermost extent of tidal influence within the stream to the upper intertidal line on the delta face. Their abundant food supply, wide salinity gradients, and diverse habitats make these areas particularly valuable to anadromous fish for rearing, feeding, and osmoregulatory acclimation during transition between fresh water and marine habitats (Macdonald et al 1987). The vital role estuaries play in chum salmon ecology is well documented (Walters et al. 1978; Healy 1980A, Levy and Northcote 1982). Other species of salmonids that also inhabit estuaries, sometimes in high densities, include coho (Tschaplinski 1982, Mason 1974, Miller and Simenstad 1997, Nielsen 1994, Hiss 1994), sockeye (Healy 1980A), pinks (Hiss 1994), and Chinook (Levy and Northcote 1982, Healy 1980A, Healy 1980B, Congleton et al 1981, Shreffler et al 1992). According to Levy and Northcote (1982), significant estuary rearing by chum and Chinook fry on the Fraser River Delta extends even into tidal channels that are dewatered during normal low tides. In the Skagit River estuary, Beamer and LaRock (1998) found high densities of Chinook, chum, and smelt inhabiting a salt marsh tidal channel (Browns Slough) that was not associated with any freshwater stream. Also found in Browns Slough were Coho smolts and adult cutthroat trout engorged on smelt. Juvenile Chinook have been documented in at least two Puget Sound estuarine salt marshes not associated with Chinook spawning streams - Shine Creek on the Olympic Peninsula (Lichatowich 1993) and Seabeck Creek on the Kitsap Peninsula (Hirschi, personal communication).

THE RELATIVE ROLE OF HABITAT IN HEALTHY POPULATIONS OF NATURAL SPAWNING SALMON

During the last 10,000 years, Washington State salmon populations have evolved in their specific habitats (Miller, 1965). Water chemistry, flow, and the physical stream components unique to each stream have helped shape the characteristics of each salmon population, which has resulted in a wide variety of distinct salmon stocks for each salmon species throughout the State. Within a given species, stocks are units that do not extensively interbreed because returning adults rely on a stream's unique chemical characteristics to guide them to their natal grounds to spawn. This maintains the separation of stocks during reproduction, thus maintaining the distinctiveness of each stock.

Throughout the salmon's life cycle, the dependence between the stream and a stock continues. Adults spawn in areas near their own origin because survival favors those that do. The timing of juveniles leaving the river and entering the estuary is tied to high natural river flows. It is thought that the faster speed during out-migration reduces predation on the young salmon and perhaps is coincident to favorable feeding conditions in the estuary (Wetherall, 1972). These are a few examples that illustrate how a salmon stock and its environment are intertwined throughout the entire life cycle.

Salmon habitat includes the physical, chemical and biological components of the environment that supports salmon. Within freshwater and estuarine environments, these components include water quality, water quantity or flows, channel physical features, riparian zones, sediment regime, upland conditions, and ecosystem interactions as they pertain to habitat. However, these components closely intertwine. Low stream flows can alter water quality by increasing temperatures and decreasing oxygen levels. The riparian zone interacts with the stream environment, providing nutrients and a food web base, large woody debris for habitat and flow control (stream features), filtering water prior to stream entry (water quality), sediment control and bank stability, and shade to aid in temperature control.

Salmon habitat includes clean, cool, well-oxygenated water flowing at a normal (natural) rate for all stages of freshwater life. In addition, salmon survival depends upon specific habitat needs for the different life history stages, which include egg incubation, juvenile rearing, migration of juveniles to saltwater, estuary rearing, ocean rearing, adult migration to spawning areas, and spawning. These specific needs can vary by species and even by stock.

When adult salmon return to spawn, they not only need adequate flows and water quality, but also unimpeded passage to their natal grounds. They need deep pools for resting with vegetative cover and instream structures such as rootwads for shelter from predators. Successful spawning depends on sufficient gravel of the right size for that particular population, in addition to the constant need of adequate flows and water quality, all in unison at the necessary location. Delayed upstream migration can be critical. After entering freshwater, most salmon have a limited time to migrate and spawn, in some cases, as little as two to three weeks. Delays can result in pre-spawning mortality or spawning in a sub-optimum location.

After spawning, the eggs need stable gravel that is not choked with sediment. River channel stability is vital at this life history stage for all species of salmonids. Floods have their greatest impact to salmon populations during incubation, and flood impacts are worsened by human activities that alter stream hydrology. In a natural river system, the upland areas are forested, and the trees and their roots store precipitation, which slows the rate of storm water into the stream, lessening the impact of a potential flood. The natural, healthy river is sinuous and contains numerous large pieces of wood contributed by an intact, mature riparian zone. Both reduce the energy of water moving downstream. Natural systems have floodplains that are connected directly to the river at many points, allowing wetlands to store flood water and later discharge this storage back to the river during lower flows. This not only decreases flood impacts, but also recharges fish habitat later when flows are low. In a healthy river, erosion or sediment input is great enough to provide new gravel for spawning and incubation, but does not overwhelm the system, raising the riverbed and increasing channel instability. Lastly, a natural river system allows floodwaters to freely flow over unaltered banks rather than constraining the energy within the channel, scouring out salmon eggs. A stable egg incubation environment is essential for all salmon, and is a complex function of nearly all habitat components.

Once the young fry leave their gravel nests, certain species such as chum, pink and some Chinook salmon quickly migrate downstream to the estuary. Other species, such as Coho, steelhead, bulltrout, and Chinook, will search for suitable rearing habitat within the side sloughs, side-channels, spring-fed "seep" areas, as well as the outer edges of the stream. These quiet-water side margin and off-channel slough areas are vital for early juvenile habitat. The presence of woody debris and overhead cover aid in food and nutrient inputs as well as provide protection from predators. For most of these species, juveniles use this type of habitat in the spring. Most sockeye salmon populations quickly migrate from their gravel nests to larger lake environments where they have unique habitat requirements. These include water quality sufficient to produce the necessary complex food web to support one to three years of salmon growth in that lake habitat prior to outmigration to the estuary.

As growth continues, the juveniles (parr) move away from the quiet shallow areas to deeper, faster areas of the stream. These include Coho, steelhead, bull trout/Dolly Varden, and certain Chinook. For some of these species, this movement is coincident with the summer low flows. Low flows constrain salmon production for stocks that rear within the stream. In non-glacial streams, summer flows are maintained by precipitation, connectivity to wetland discharges, and groundwater inputs. Reductions in these inputs will reduce the amount and quality of habitat; hence the number of salmon from these species.

In the fall, juvenile salmon that remain in freshwater begin to move out of the mainstems, and again, off-channel habitat becomes important. During the winter, Coho, steelhead, bull trout/Dolly Varden, and remaining Chinook need habitat to sustain their growth and protect them from predators and winter flows. Wetlands, off-channel habitat, undercut banks, rootwads, and pools with overhead cover are important habitat components during this time.

Except for bull trout/Dolly Varden and resident steelhead, juvenile parr convert to smolts as they migrate downstream towards the estuary. Again, flows are critical, and food and shelter are necessary. The natural flow regime in each river is unique, and has shaped the population's characteristics through adaptation over the last 10,000 years. Because of the close inter-relationship between a salmon stock and its stream, survival of the stock depends on natural flow patterns, particularly during migration times.

The estuary provides an ideal area for rapid growth, and some salmon species are heavily dependent on estuaries, particularly Chinook, chum, and to a lesser extent, pink salmon. Estuaries contain new food sources to support the rapid growth of salmonid smolts, so adequate natural habitat must exist to support the detritus-based food web, such as eelgrass beds, mudflats, and salt marshes. Also, the processes that contribute nutrients and woody debris to these environments must be maintained to provide cover from predators and to sustain the food web. Common disruptions to these habitats include dikes, bulkheads, dredging and filling activities, pollution, and alteration of downstream components such as lack of woody debris and sediment transport.

All salmonid species need adequate flow, similar water quality, spawning riffles and pools, a functional riparian zone, and upland conditions that favor stability, but some of these specific needs vary by species, such as preferred spawning areas and gravel. Although some overlap occurs, different salmon species within a river are often staggered in their use of a particular type of habitat. Some are staggered in time, and others are separated by distance.

Chum and pink salmon use the streams the least amount of time. Washington State adult pink salmon typically begin to enter the rivers in August and spawn in September and October, although Dungeness summer pinks enter and spawn a month earlier (WDFW and WWTIT, 1994). During these times, low flows and associated high temperatures and low dissolved oxygen can be problems. Other disrupted habitat components, such as shallow and less frequent pools due to elevated sediment inputs and lack of canopy from an altered riparian zone or widened river channel, can worsen these flow and water quality problems because there are fewer refuges for the adults to hold prior to spawning.

The pink salmon fry emerge from their gravel nests in February to April, and migrate downstream to the estuary within a month. After a limited rearing time in the estuary, pink salmon migrate to the ocean for a little over a year, until the next spawning cycle. Most pink salmon stocks in Washington are only in the rivers in odd years. The exception is the Snohomish Basin, which supports two pink salmon stocks. One stock spawns in odd years, and the other stock spawns in even years.

In Washington, adult chum salmon (3-5 years old) have three major run types. Summer chum enter the rivers in August and September, and spawn in September and October. Fall chum adults enter the rivers in late October through November, and spawn in November and December. Winter chum enter from December through January and spawn from January through February. Chum salmon fry emerge from the nests in March and April, and quickly outmigrate to the estuary for rearing. In the estuary, juvenile chum follow prey availability. In Hood Canal, juveniles that arrive in the estuary in February and March migrate rapidly offshore. This migration rate decreases in May and June as levels of zooplankton increase. Later as the food supply dwindles, chum move offshore and switch diets (Simenstad and Salo, 1982). Both chum and pink salmon have similar habitat needs such as unimpeded access to spawning habitat, a stable incubation environment, favorable downstream migration conditions (adequate flows in the spring), and because they rely heavily on the estuary for growth, good estuary habitat is essential.

Chinook salmon have three major run types in Washington State. Spring Chinook are in their natal rivers throughout the calendar year. Adults begin river entry as early as February in the Chehalis Basin, but in Puget Sound, entry doesn't begin until April or May. Spring Chinook spawn from July through September and typically spawn in the headwater areas where higher gradient habitat exists. Incubation continues throughout the autumn and winter and generally requires more time for the eggs to develop into fry because of the colder water temperatures in the headwater areas. Fry begin to leave the gravel nests in February through early March. After a short rearing period in the shallow side margins and sloughs, all Puget Sound and coastal spring Chinook stocks have a component of the juvenile population that begin to leave the rivers to the estuary over the next several months, lasting until August. Within the Puget Sound stocks, it is not uncommon for other juveniles to remain in the river for another year before leaving as yearlings, so that a wide variety of outmigration strategies are used by these stocks. The juveniles of spring Chinook stocks in the Columbia Basin exhibit more distinct juvenile life history characteristics. Generally, these stocks remain in the river for a full year. However, some stocks migrate downstream from their natal tributaries in the fall and early winter into larger rivers, including the mainstem Columbia River, where they are believed to over-winter prior to outmigration the next spring as yearling smolts.

Summer Chinook begin river entry as early as June in the Columbia, but not until August in Puget Sound. They generally spawn in September or October. Fall Chinook stocks range in spawn timing from late September through December. All Washington State summer and fall Chinook stocks have juveniles that incubate in the gravel until January through early March, and downstream migration to the estuaries occurs over a broad time period (January through August). A few of these stocks have a component of juveniles that remains in freshwater for a full year after emerging from the gravel nests.

While some emerging Chinook salmon fry outmigrate quickly, most inhabit the shallow side margins and side channels for up to two months. Then, some gradually move into the faster areas to rear, and others outmigrate to the estuary. Most summer and fall Chinook outmigrate within their first year of life, but a few stocks (Snohomish summer Chinook, Snohomish fall Chinook, upper Columbia summer Chinook) have juveniles that remain in the river for an additional year, similar to many spring Chinook (Marshall et al, 1995). However, those in the upper Columbia, have scale patterns that suggest that they rear in a reservoir-like environment (mainstem Columbia River upstream from a dam) rather than in their natal streams and it is unknown whether this is a result of dam influence or whether it is a natural pattern.

The onset of Coho salmon spawning is tied to the first significant fall freshet (Chuck Baranski, WDFW, Pers. comm.). Adults typically enter freshwater from September to early December, but have been observed as early as late July and as late as mid-January (WDF et al, 1993). They often mill near the river mouths or in lower river pools until freshets occur. Spawning usually occurs between November and early February, but is sometimes as early as mid-October and can extend into March. Spawning often occurs in tributaries and sedimentation in these tributaries can be a problem, with fine sediments suffocating eggs and excess coarse sediment decreasing channel stability. As Chinook salmon fry exit the shallow low-velocity rearing areas, Coho fry enter the same areas for the same purpose. As they grow, juveniles move into faster water and disperse into tributaries and areas that adults cannot access (Neave 1949). Pool habitat is important not only for returning adults, but for all stages of juvenile development. Preferred pool habitat includes deep pools with riparian cover and woody debris.

All Coho juveniles remain in the river for a full year after leaving the gravel nests, but during their first summer after hatching, low flows can lead to problems such as physical reduction of available habitat, increased stranding, decreased dissolved oxygen, increased water temperature, and increased predation. Juvenile Coho are highly territorial and can occupy the same area for a long period of time (Hoar, 1958). Coho abundance can be limited by the number of available suitable territories (Larkin, 1977). Streams with more structure (logs, bushes, etc.) support more Coho (Scrivener and Andersen, 1982), not only because they provide more territories, but they also provide more food and cover. There is a positive correlation between their primary diet of insect material in their stomachs and the extent to which the stream was overgrown with vegetation (Chapman, 1965). In addition, the leaf litter in the fall contributes to aquatic insect production (Meehan et al., 1977).

In the autumn as the temperatures decrease, juvenile Coho move into deeper pools, and hide under logs, tree roots, and undercut banks (Hartman, 1965). The fall freshets redistribute them (Scarlett and Cederholm, 1984), and over-wintering generally occurs in available side channels, spring-fed ponds, and other off-channel sites to avoid winter floods (Peterson, 1980). The lack of side channels and small tributaries may limit Coho survival (Cederholm and Scarlett, 1981). As Coho juveniles grow into yearlings, they become more predatory on other salmonids. Coho begin to leave the river a full year after emerging from their gravel nests with the peak outmigration occurring in early May. Coho use estuaries primarily for interim food while they adjust physiologically to saltwater.

Sockeye salmon have a wide variety of life history patterns, including landlocked populations of kokanee that never enter saltwater. Of the populations that migrate to sea, adult freshwater entry varies from spring for the Quinault stock, summer for Ozette and Columbia River stocks, and summer and fall for Puget Sound stocks. Spawning ranges from September through February, depending on the stock.

After fry emerge from the gravel, most migrate to a lake for rearing, although a few types of fry migrate to the sea. Lake rearing ranges from one to three years with most juveniles rearing two years. In the spring after lake rearing is completed, juveniles enter the ocean where more growth occurs prior to adult return for spawning.

Sockeye spawning habitat varies widely. Some populations spawn in rivers (Cedar River) while other populations spawn along the beaches of their natal lake (Ozette), typically in areas of upwelling groundwater. Sockeye also spawn in side channels and spring-fed ponds. The spawning beaches along lakes provide a unique habitat that is often altered by human activities, such as pier and dock construction, dredging, sedimentation, and weed control.

Steelhead have one of the most complex life history patterns of any Pacific salmonid species (Shapovalov and Taft, 1954). In Washington, there are two major run types, winter and summer steelhead. Winter steelhead begin river entry in a mature reproductive state in December and generally spawn from February through May. Summer steelhead enter the river from about May through October with spawning from about February through April. They enter the river in an immature state and require several months to mature (Burgner et al, 1992). Summer steelhead usually spawn farther upstream than winter stocks (Withler, 1966) and dominate inland areas such as the Columbia Basin. Coastal streams support more winter steelhead populations.

Juvenile steelhead can either migrate to sea (anadromy) or remain in freshwater as rainbow trout. In Washington, those that are anadromous usually spend one to three years in freshwater, with the greatest proportion spending two years (Busby et al, 1996). Because of this and their year-round presence in steelhead-bearing streams, steelhead greatly depend on the quality and quantity of freshwater habitat.

Bull trout/Dolly Varden stocks are also very dependent on the freshwater environment, where they reproduce only in clean, cold, relatively pristine streams. Within a given stock, some adults remain in freshwater their entire lives, while others migrate to the estuary where they rear during the spring and summer. They then return upstream to spawn in late summer. Those that remain in freshwater either stay near their spawning areas as residents, or migrate upstream throughout the winter, spring, and early summer, residing in pools. They return to spawning areas in late summer. In some stocks juveniles migrate downstream in spring, overwinter in the lower river, then enter the estuary and Puget Sound the following late winter to early spring (WDFW, 1998). Because these life history types have different habitat characteristics and requirements, bull trout/Dolly Varden are generally recognized as a sensitive species by natural resource agencies. Reductions in their abundance or distribution are inferred to represent strong evidence of habitat degradation.

In addition to the above-described relationships between various salmon species and their habitats, there are also interactions between the species that have evolved over the last 10,000 years such that the survival of one species might be enhanced or impacted by the presence of another. Pink and chum salmon fry are frequently food items of Coho smolts, Dolly Varden char, and steelhead (Hunter, 1959). Chum fry have decreased feeding and growth rates when pink salmon juveniles are abundant (Ivankov and Andreyev, 1971), probably the result of occupying the same habitat at the same time and competing for food items. These are just a few examples.

Most streams in Washington are home to several salmonid species, which together, rely upon freshwater and estuary habitat the entire calendar year. As the habitat and salmon review indicated, there are complex interactions between different habitat components, between salmon and their habitat, and between different species of salmon. For just as habitat dictates salmon types and production, salmon production contributes to habitat and to other species.

WATERSHED DESCRIPTION AND CONDITION FOR STREAMS IN WRIA 12

Location and Watershed Characteristics

WRIA 12 is located in central Pierce County and is roughly triangular in shape, bounded by Puget Sound on the west, and extends east to near the community of Graham. Point Defiance and the southwest shore of Commencement Bay serve as the WRIA's northern boundary. The City of DuPont near the Nisqually River Basin is located near the southern boundary. The WRIA covers approximately 180 square miles (Clothier, et al 2003). WRIA 12 comprises the Chambers-Clover Creek Basin and the neighboring small drainages of Sequalitchew (including American Lake and Murray Creek) and Puget Creeks in Pierce County, Washington. It also encompasses several independent stream drainages, including unnamed creeks draining from the North Tacoma area directly into Puget Sound, and Crystal Springs Creek. Important lakes within WRIA 12 are Lake Louise, Owens Marsh, and Steilacoom, Gravelly, American, Spanaway, Waughop, Charlton, and Wapato Lakes (Clothier, et al 2003).

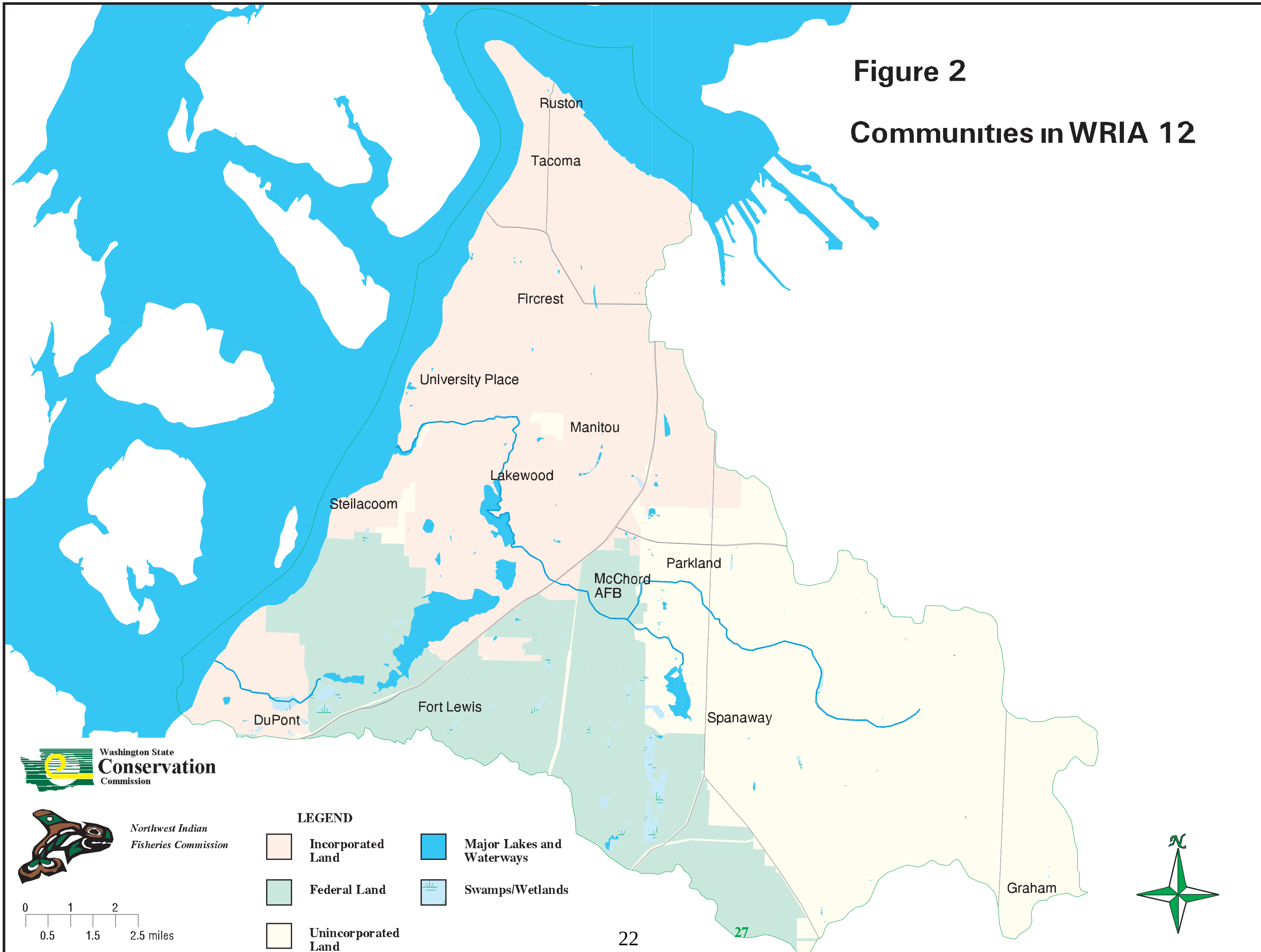
The watershed lies within the central part of the Puget Sound Lowland, an elongated topographic and structural trough that extends from the Canadian Border to the Willamette Valley in Oregon. The Puget Lowland is bounded on the east by the Cascade Mountains and on the west by the Olympic Mountains and the Willapa Hills. Lowland topography is generally flat and elevations within the watershed range from sea level to 600 feet (PCPWU:WAP 1996) (See Appendix E: WRIA 12 Elevation Model).

WRIA 12 includes approximately the western half of the City of Tacoma, all of the Cities of Lakewood and University Place, and the Towns of Steilacoom, Dupont, Fircrest, and Ruston. It also includes the unincorporated communities of Parkland, Spanaway, Elk Plain, Frederickson, and Midland. McChord Air Force Base and part of Fort Lewis occupy a large portion of the central and southern part of the basin (Clothier, et al 2003) (See Figure 2).

The steady pace of urbanization in this watershed has led to declining fisheries resources in WRIA 12 for over a century, with the exception of hatchery-raised fall Chinook salmon. Many alterations have been made to the streams and overall watershed in WRIA 12, beginning as early as 1853 and accelerating in the late 1800s (Consoer and Townsend 1977). Trends in fisheries production/escapement appear to be linked to habitat conditions, such as stream flow, water quality, human harvest, and natural predation. Human use and development have been major contributors to the current conditions. Impervious surfaces, runoff, pollution, and water consumption have taken their toll on WRIA 12 (Clothier, et al 2003).

Figure 2

Communities in WRIA 12



Chambers-Clover Creek

Of the three major subdivisions of WRIA 12, the Chambers-Clover Creek watershed is the largest. The headwaters of this watershed originate from spring and groundwater run-off on the flat plateau at the 400-foot elevation of the South Tacoma District and flow 18.1 miles northwest, entering southern Puget Sound one mile north of the community of Steilacoom. Clover Creek is the uppermost basin in the system and originates from springs and groundwater drainage approximately 6.0 miles east of Spanaway in the Spanaway-Parkland residential districts east of McChord Air Force Base. It drains northwesterly through McChord Field into the high-density residential and business district of Lakewood where it enters Steilacoom Lake.

Steilacoom Lake (313 surface acres) was created in 1852 when early settlers built a dam (at RM 4.1) on Chambers Creek (Lakewood Community Plan 1991, cited in PCPWU 1997). The dam at the outlet now controls the lake elevation. By 1975 the dam was found to be a total blockage to anadromous fish passage (Williams 1975). Since then, fish ladders have been installed at the dam to facilitate passage for spawning salmon (Tetra Tech 2000, cited in Clothier, et al 2003).

Clover Creek's North Fork begins as seasonal surface runoff on a plateau three miles east of Parkland and flows 3.2 miles northwesterly through the heavily developed residential and business districts of Parkland before joining Clover Creek on the east portion of McChord AFB.

Spanaway Creek, a tributary of Clover Creek, is formed by springs and marshes on Ft. Lewis, and flows north as a stream locally referred to as Coffee Creek until it flows into Spanaway Lake. The stream drains through Spanaway Lake and converges with Clover Creek at RM 9.2 on McChord AFB approximately one-quarter mile after flowing through Tule Lake.

Dense residential, commercial, and military development encroaches upon most of the Clover Creek main stem from Steilacoom Lake to the confluence with the North Fork (Tetra Tech/KCM 2002).

Figure 3: One of the 12 ft diameter pipes rolled in place in the McChord Airbase channel in 1939
(Photo from Tacoma Public Library, courtesy of Fred Tobiason)

A unique characteristic of this creek is that it is contained within a 0.6 mile long underground culvert below the runways at McChord Air Force Base before passing under the I-5 freeway.

Encroaching development is also a problem on the North Fork of Clover Creek, from the downstream end of Tule Lake Road to 138th Street East. Low-density residential development and agricultural practices frequently encroach upon the banks of Clover Creek upstream of the North Fork confluence. In addition, dredging and channeling of the creek throughout this subbasin have contributed to intermittent flows and water loss (Tetra Tech/KCM 2002).

From the outflow of Steilacoom Lake, Chambers Creek flows north for 1.5 miles and then west through a narrow, steep-sided ravine for 2.6 miles until it enters Chambers Bay. A dam with a spillway and fish ladder forms the head of Chambers Bay, the beginning of the tidal influence, approximately 0.75 miles upstream from the Northern Pacific Railroad dike across the mouth of the bay. The outlet of Chambers Bay to Puget Sound is very narrow and restricted due to the railroad dike and bridge across the mouth of the bay.

Nearly three decades ago, Williams (1975) observed that Chambers Creek had widths to 25 feet and varied in depth from 6 inches to 2 feet. It contained excellent gravel and good pool-riffle ratios with a moderate gradient. It generally had all the characteristics of a typical lowland-type stream with stable bank areas. Deciduous trees and growth overhung the banks and provided excellent shade and cover except in the upper section where residences abutted the stream. Because Pierce County owns much of the ravine and has protected it, these observations are still generally true. More specific information on the creek is discussed in the Chambers Creek section.

Natural springs, surface, and groundwater contribute to Clover Creek, North Fork Clover Creek, Flett Creek, Leach Creek, Ponce de Leon Creek, and Spanaway Creek. There are several larger lakes plus many small lakes, ponds, and marsh areas that directly or indirectly provide seepage to this system to sustain summer flows.

Lakes, ponds, and marshes in the Manitou and Fircrest area provide groundwater seepage into Flett and Leach creeks, the two major tributaries to the lower Clover/Chambers Creek drainage. Flett Creek originates near the community of Manitou and flows west 3.1 miles and converges at RM 2.55 on Chambers Creek; Leach Creek originates near Fircrest and flows south 2.3 miles where it joins Chambers Creek at RM 2.4. Approximately 9.4 stream miles are accessible to salmon utilization in the Chambers Creek drainage (Williams 1975).

Williams (1975) described Leach Creek as a small tributary varying in width from 6 to 15 feet and from 6 inches to 2 feet in depth, containing a good gravel and pool-riffle balance. Housing developments were located along the upper section of the creek where stream cover had been removed. Otherwise, bank cover consisted of deciduous trees in the canopy along with underbrush, interspersed with open meadow (once farmland). Flett Creek also contained good gravel and pool-riffle balance in the lower half of the stream.

Sequalitchew Creek

The Sequalitchew Creek watershed lies south of Tacoma between the communities of DuPont, Fort Lewis, and Lakewood and drains an area of 38.4 square miles (Clothier, et al 2003).

Kinsey Marsh, which lies south of McChord Air Force Base, is the beginning of the upper watershed. Murray Creek drains this marsh and flows south and west through the center of Fort Lewis. It flows under I-5 and through the Camp Murray National Guard Station. Then, after 3.8 miles, it enters American Lake

(1,162 surface acres) on the southeast shoreline. One section of the creek was modified and deepened in the 1940s so that soldiers could be trained to cross 6 foot deep streams. The creek is currently experiencing flows much lower than historic levels, and invasive, non-native plant species have overrun the creek (PCPWU 1997).

The overflow from American Lake historically drained into Sequalitchew Lake (80.9 surface acres) (Wolcott 1973). Though it appears that this connection is now severed and the only connection between the two lakes is underground, Fort Lewis officials report that a connection remains through a canal system constructed by Pierce County (Crown, Pers. comm., 2003). Sequalitchew Lake has its own overflow outlet that forms the beginning of Sequalitchew Creek. The water level of both lakes is maintained year round by springs and water table seepage (PCPWU 1997).

A diversion dam for overflow water from the lake, built by Fort Lewis around 1950, lies near the outflow of Sequalitchew Lake. The dam directs water through a canal that originates in Hamer Marsh, east of the creek. Just south of Sequalitchew Lake, the canal passes under the creek through a series of culverts. The canal continues west for one mile, and turns north to empty into Puget Sound at Tatsolo Point. There is disagreement as to the effect of this canal system upon the Creek. Andrews and Swint (1994) reported that the diversion dam and canal structure is a tangled arrangement (See Figure 4: Diagram of Diversion Dam / Canal Structure at Outlet of Sequalitchew Lake) and the effects of this structure on the creek are significant. Fort Lewis officials report that the effects of this structure on Sequalitchew Creek are not significant, and that the structure was constructed to maintain the lake level and flow to Sequalitchew Creek (Crown, Pers. comm., 2003).

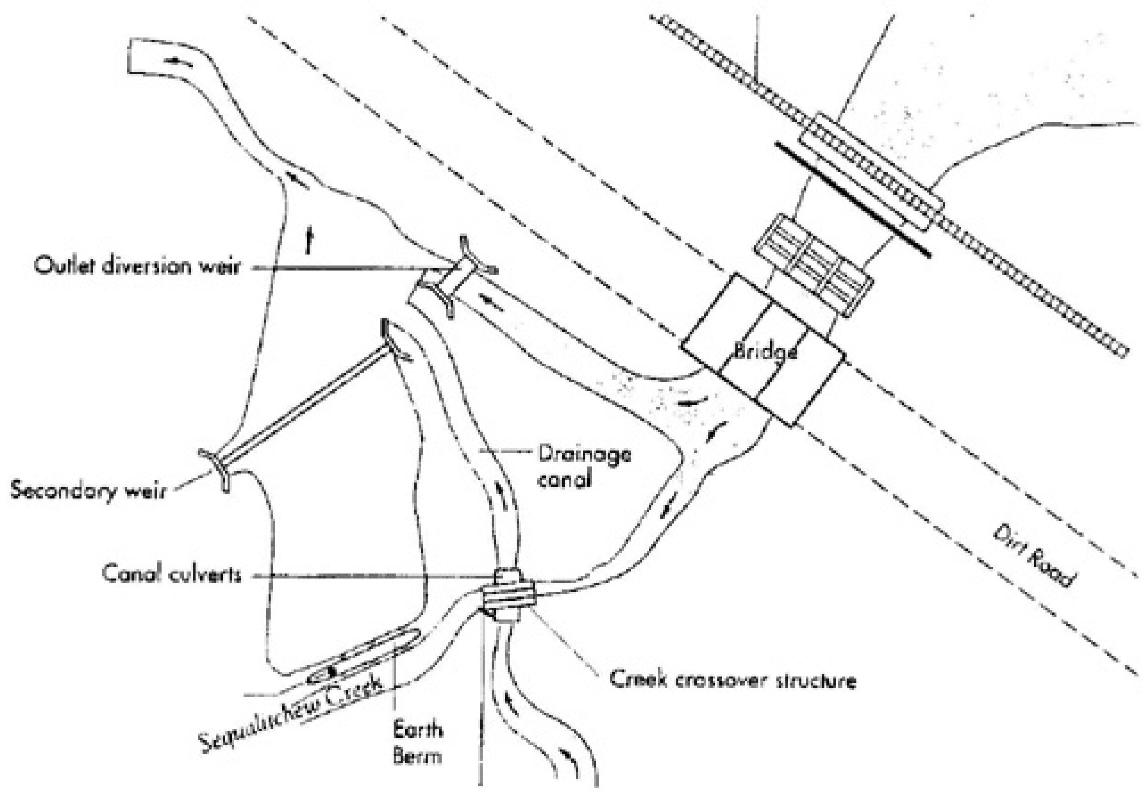


Figure 4: Diagram of Diversion Dam / Canal Structure at Outlet of Sequalitchew Lake
(Courtesy Dave Clouse, Ft. Lewis Army Base)

From its origins at the lake, Sequalitchew Creek drains westerly for 0.5 miles in a dredged channel along the edge of Hamer Marsh on the Fort Lewis Military Reservation. The creek then flows through Edmond Marsh and across more than 1 mile of former DuPont Powder Company – now Weyerhaeuser – property. Each of these marshes has more than 100 surface acres. The creek descends 200 feet in elevation through a steep-sided ravine in the lower 1.5 miles, where it abruptly enters salt water south of the old DuPont Wharf location (PCPWU 1997), which has recently been removed.

At this junction with the marine environment, the stream passes through a large culvert under the dike supporting the Northern Pacific and Burlington Northern railroad tracks. Little natural estuary is present, but the extensive Nisqually Flats that lie immediately to the south of the creek mouth provide estuarial rearing for salmon smolts from this system (Williams 1975). Sequalitchew Creek has historically supported runs of Coho salmon up to approximately RM 3.0 and chum salmon have been observed spawning in the lower 200 yards (Williams 1975).

Independent Tributaries

Several independent streams in WRIA 12 drain directly into Puget Sound. Notable among these are Puget Creek and the Fifth Street Waterway in Steilacoom.

Puget Creek is a small perennial stream, approximately 1,648 feet long, draining down Puget Gulch directly to the northwest portion of Commencement Bay. It is formed by several springs, the seepage from three tributaries in the upper half of the stream, and flow from off-channel ponds and three small, year-round streams in the lower half (PCRS 2002). Much of the flow in Puget Creek has been incorporated into a storm drainage system which runs the length of Puget Gulch. The gulch has steep sides and 150 foot bluffs that extend from Tyler and 33rd to Cedar and 16th in Tacoma (Isensee, Pers. comm., 1994, cited in PCPWU 1997).

The creek enters salt water via a culvert under Ruston Way. The outfall from the culvert is similar to the situation at Sequalitchew Creek, being perched above the immediate shoreline. The shoreline in this area is a combination of sandy beaches, riprap, and concrete bulkheads. To migrate upstream, fish need to access the culvert opening on incoming high tides (Clothier, et al 2003).

Due in part to cooperative restoration efforts for the past 15 years, Coho and chum have begun to use the system. Adult Coho spawning activity and redds as well as cutthroat in various life stages have been observed in this stream (PCRS 2002).

The Fifth Street Waterway (LLID 1226069471699) is a small, independent tributary entering the east bank of Puget Sound in a small inlet near the north end of 5th Street in the City of Steilacoom. It originates in Farrell Marsh, and flows for approximately one mile northwest before entering salt water. The use of this stream by Coho and cutthroat has been documented, while its use by chum salmon is anecdotal and presumed (Marcantonio, Pers. comm., 2003).

Climate/Hydrology

The climate within the watershed is mild with average winter temperatures above freezing and summer temperatures generally below 80°F. The watershed experiences a frost-free growing season of approximately 250 days per year. Typically, 38 to 40 inches of precipitation occurs per year; about two-thirds falls between October and March of each year (PCPWU:WAP 1996).

First flush conditions generally occur in September. A first flush event is a rain event that occurs after an extended period of little or no rainfall. In these instances, the rain washes pollutants off of surfaces where they have been collecting during the dry period. Storm water runoff typically contains higher concentrations of pollutants during first flush events (PCPWU 1997).

Because highly permeable gravelly soils derived from glacial outwash cover so much of WRIA 12, it is estimated that approximately 50% to 60% of the watershed's precipitation becomes groundwater recharge. Precipitation is estimated to recharge the Chambers-Clover Creek Basin at a rate of 120,300 acre-feet per year. Infiltration from precipitation accounts for about 66% of the total basin recharge. Storm water contributes 21% to the recharge budget, septic tanks make up 11%, and surface water bodies contribute 2%. The depth to groundwater in the basin ranges from 0 to more than 100 feet. Most of the groundwater in the watershed moves at an average rate of about 4.4 feet per day to the west toward Puget Sound (PCPWU:WAP 1996).

The topography of the Sequalitchew Subbasin is fairly flat and, as a result, surface water tends to concentrate into lakes and wetlands. Groundwater also has an important hydrologic role within this watershed and supplies water to American Lake, Gravelly Lake, Lake Louise, Sequalitchew Lake, Sequalitchew Creek and many wetlands (PCPWU 1997).

Geology (from PCPWU 1997)

Two hundred million years ago the land area now occupied by the Chambers-Clover Creek Watershed was located at the bottom of a shallow sea. About 50 million years ago, volcanic activity caused the sea to retreat and the land to slowly rise. Volcanic activity, lava flows, and the folding of the earth's crust continued to influence the shape of the land, causing the Cascade and Olympic mountain ranges to begin forming about 7 million years ago. From two and one-half million years ago to 11,000 years ago, the Chambers-Clover Creek Watershed area experienced a number of glacial advances and retreats. Those glaciers have had a tremendous impact on the way surface and ground water moves in the area today (Brown & Caldwell 1985).

Because of these glacial advances and retreats, the watershed has complex geology. The most significant geologic features in the area produced by glacial activity are the layers of glacial outwash and glacial till. Glacial outwash refers to the material that is carried by the glacier as it advances and is deposited by the meltwater as the glacier retreats. Clean, unconsolidated sediments with significant proportions of medium sized, rounded rocks are often indicators of glacial outwash. These sediments are traditionally found to be very well drained. Glacial till is often referred to as hardpan. It is a layer of sediments which has been compacted by the weight of the glacier and contains enough small particles such as clay to make it relatively impermeable. These layers of glacial till are often characterized by concrete-like hardness and are virtually impermeable to water. The Chambers-Clover Creek Watershed does have areas where the lack of clay content has resulted in till layers that water is still able to permeate through. Because the area has experienced a number of glacial events, several alternating layers of till and outwash form the subsurface sedimentary layers of the watershed (Brown & Caldwell 1985).

Till generally impedes vertical migration of water. These dense layers trap water in the gravelly soils above them and create an aquifer, or volume of subsurface water. Till layers also cause ground water to move horizontally and supply water to many of the lakes in the western portion of this watershed, most of which have limited or no surface water sources. Water and contaminants can still migrate down through till layers but at exceptionally slow rates. However, the porous outwash layers between the till allow for rapid horizontal transportation of contaminants (Brown & Caldwell 1985).

Material from the most recent glacial event, the Vashon glaciation, covers the Chambers-Clover Creek Watershed in a layer which varies in depth from 0 to 350 feet and includes advance outwash material, till, and recessional outwash material from the Vashon glaciation. The average depth of the outwash layer is about 100 to 200 feet deep. The till layer averages 5 to 30 feet thick but some well logs have indicated sheets of till up to 100 feet thick. In the northwestern area of the watershed, the till layer outcrops at the surface (Brown & Caldwell 1985).

The Steilacoom gravels were created by a special type of glacial process. There was a point at which the Vashon glacier created an immense lake in the area currently occupied by the Puyallup River Valley. When the glacier broke, the water from the lake flooded west, cutting the Clover Creek channel and the South Tacoma channel. This type of high energy flooding action caused a tremendous amount of outwash material to be transported into the western area of the watershed (Brown & Caldwell 1985). As a result, Steilacoom gravels are made up almost entirely of loosely sorted rocks and sand. These gravels are valued as a source of high quality construction materials.

Soil Associations

The three most common soil associations surveyed by NRCS soil scientists within the Chambers-Clover Creek Watershed are the Kapowsin, Spanaway, and Alderwood-Everett Associations. Inclusions of other soils within these associations do occur. When those inclusions are of poorly drained soils, a wetland may result. Soils commonly associated with wetlands in the watershed include DuPont muck, Tisch silt, Bellingham loam, Norma loam, and McKenna loam (USDA 1979).

Kapowsin Association

This association is characterized by rolling uplands with poorly defined drainage channels. The soil is moderately well-drained and tends to foster higher levels of surface water runoff than other associations. It is common to find a cemented hard pan layer underlying this association. The erosion potential is moderate depending upon the slope (USDA 1979).

Spanaway Association

This association is characterized by nearly level uplands. This soil is excessively well-drained, provides a good source of gravel, and has a low potential for erosion (USDA 1979).

Alderwood-Everett Association

These soils are characterized by gently rolling uplands which break into steep canyons. The canyons are formed by creeks, such as Chambers Creek, crossing through these associations and eroding away the surface soils. Much of the Puget Sound shoreline within the watershed is bordered by Alderwood soils which have been eroded into steep bluffs.

Alderwood soils are moderately well-drained but are often underlain by a layer of compacted glacial till. This layer of till limits the capacity of this soil to retain water so areas with slopes may experience medium to rapid surface runoff and moderate to severe erosion hazard.

Everett soils are excessively well-drained. This is a highly permeable soil with low surface runoff and low erosion rates. Everett soils provide an excellent source for sand and gravel (USDA 1979).

(An elevation model of the topography of WRIA 12, developed by the Washington Department of Ecology, is available for viewing in APPENDIX .)

Land Use

Six land cover classes in the watershed were derived from satellite-remote-sensing data (PCPWU:WAP 1996). Land use was estimated through analysis of land cover data.

Agricultural land: (297 acres or 0.3% of the watershed) combines active (crops) and open (pasture) agriculture. Hobby farms, small acreage farms that typically contain livestock, are generally not detected in this class because of their small size.

Built up land: (39,785 acres or 42%) combines residential, commercial, and industrial uses. These different land uses have different percentages of impervious surface, different effects on water quality, and different implications for population growth. Data is available for the Clover Creek-Lake Steilacoom Subwatershed from the USGS which produced a report distinguishing between these different land uses.

Other natural cover: (34,099 acres, or 36%) is primarily grasses, shrubs and brush. Much of this land is under the management of Fort Lewis but also includes schools, golf courses, cemeteries, landfills, and possibly hobby farms.

Forest lands: (17,703 acres or 19%) represent deciduous, coniferous, and mixed forest plant communities.

Water: (2,126 acres or 2%) generally represents the presence of lakes.

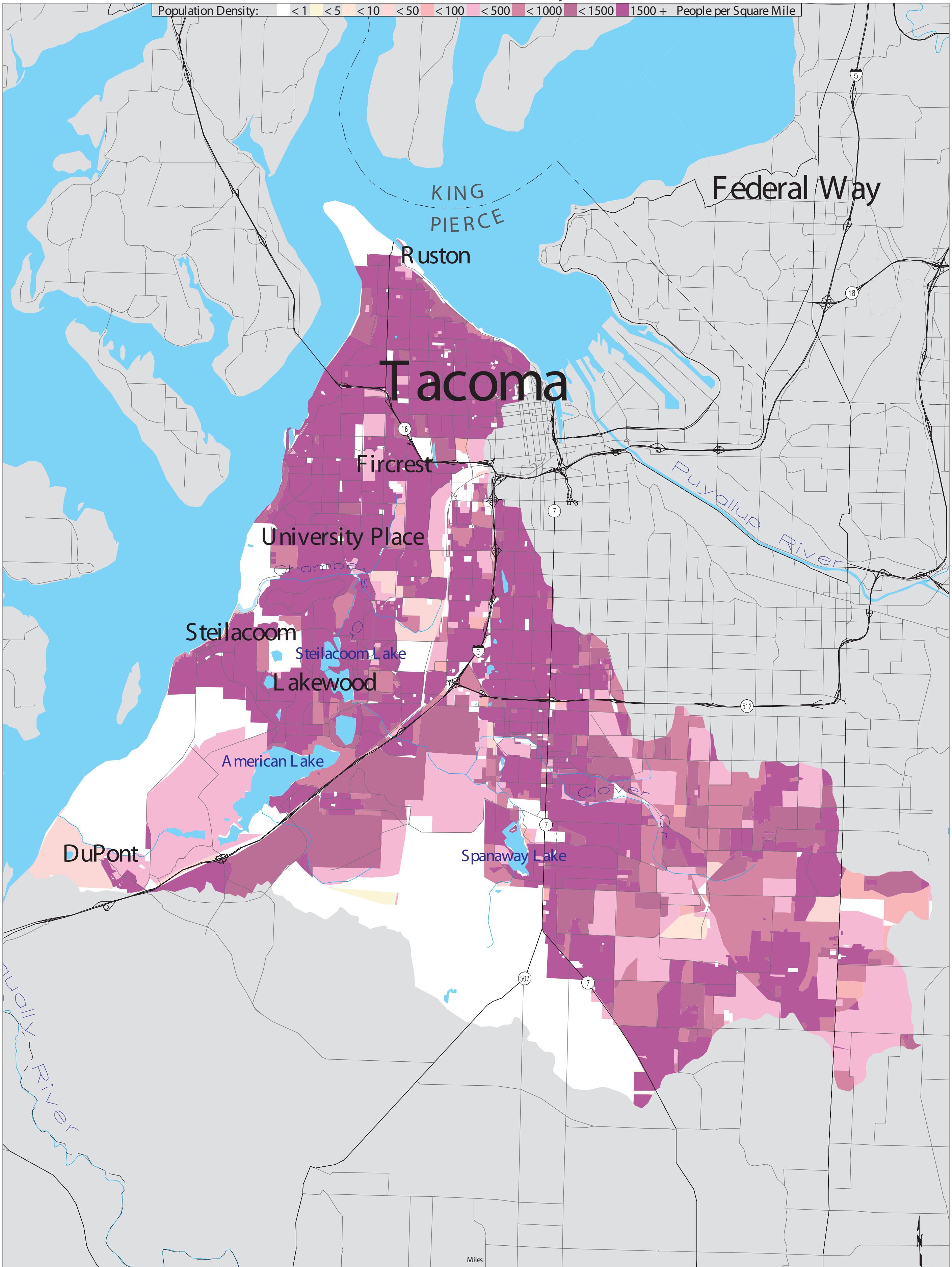
Non-vegetated cover: (1,335 acres or 1%) generally represents bare soil, gravel, and sandy areas, and bare exposed rock.

Approximately 55% of the watershed (52,000 acres) is open natural cover or forest land. 21,000 acres of this open natural cover or forest land is federally managed and not available for development. Much of the future development will be focused on approximately 30% of the watershed (25,800 acres) in the Steilacoom Lake (Clover Creek) Subwatershed. Substantial areas have been set aside for commercial and industrial uses. One-third of the future population (115,000) will reside in the Clover Creek/Lake Steilacoom Subwatershed by the year 2020. In order to accommodate this growth and future commercial zones, built-up or urban land cover will replace forested and natural cover (PCPWU:WAP 1996).

The Department of Ecology has published a map depicting the density of the population in WRIA 12 during the 2000 Census (See Figure 5). A map of Land Use/Land Cover of WRIA 12, developed by the Washington Department of Ecology, is available for viewing in APPENDIX E .

Figure 5: WRIA 12 2000 Census Population Distribution

Chambers/Clover Water Resource Inventory Area (WRIA) #12



Wa. Dept. of Ecology, GIS Technical Services 05/15/03

2000 Census Block Population

popden12

DISTRIBUTION AND CONDITION OF SALMON, STEELHEAD, AND BULL TROUT/DOLLY VARDEN STOCKS

Don Haring

General

Salmonid stock assessment data are variable within WRIA 12. Little, if any, stock assessment work has been done for either Puget Creek or Sequalitchew Creek (Baranski, Pers. comm., 2003), or for other small independent tributaries in WRIA 12. On the other hand, detailed spawner escapement data are available for Chambers Creek for most salmonid species.

Anadromous adult salmonids returning to Chambers Creek are enumerated at a trap located at the dam at the upper end of Chambers Bay. The trap is typically operated from mid-August through the first week of February (Eltrich, Pers. comm., 2003). Through the period of Chinook and Coho returns, the trap is checked approximately three times per week; all Chinook are removed from the trap and contribute to the composite South Puget Sound hatchery Chinook program. Adult returns of other incidental species, including all Coho, are passed upstream during this period. During the winter chum return, returning adults are counted electronically and are able to freely pass upstream through the trap. Supplemental chum spawning ground surveys are done in the Chambers Creek watershed to provide information on spawning distribution; incidental Coho distribution observations are also made during these chum surveys. Adult salmonids returning from the time the trap is removed in February to when it is again installed in August are able to ascend upstream unimpaired, but are not enumerated.

Chinook

In the 2002 Salmon and Steelhead Inventory (SaSI, WDFW 2003 Draft), the co-managers state that the fall Chinook spawning in generally small independent South Sound streams (including Chambers Creek) are not regarded as being a distinct stock and have not been rated as such. This assessment was based on the following rationale: (1) The independent tributaries in south Puget Sound are not typical Chinook habitat because of relatively small stream size and low flows during the late summer/early fall spawning season. (2) The current low escapements (outside of streams that support on-station Chinook production programs) are likely the result of past hatchery plants or straying from either current south Sound hatchery production or viable south Sound natural populations. (3) Fall Chinook likely were not historically self-sustaining in these habitats and have little chance of perpetuating themselves through natural production.[1]

Chambers Creek Chinook returns are predominantly due to the large releases of hatchery-origin fish in this basin. Locally-returning Chinook are now used for the primary broodstock source for these programs, but their ancestry is largely Soos Creek Hatchery (Green River) Chinook.

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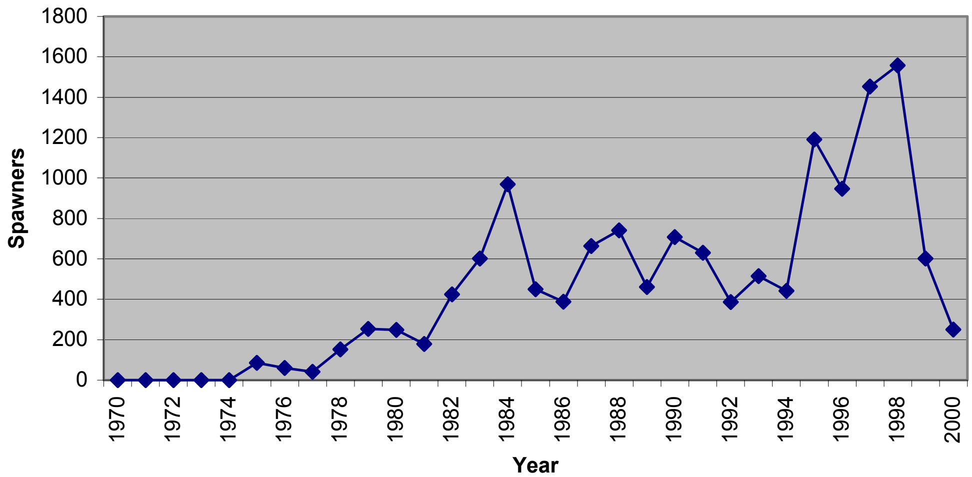
[1] There is professional disagreement among biologists regarding the historical presence of Chinook in the Chambers-Clover system. Pierce County EDT (Mobrand Biometrics, 2001) results support a population of about 2,000 Chinook in the creek system using a biometric modeling system. Although this estimate may be somewhat high, it may indicate that a self-sustaining population once existed. This population may have been supplemented by strays from larger systems nearby (Nisqually & Puyallup Rivers, for example). If this is true, Chambers-Clover Chinook would have been an important stock, if only for the purpose of fostering greater genetic diversity of the meta-population for South Puget Sound Chinook (Kantz, Pers. comm., 2003).

Adult Chinook returns to Chambers Creek are intercepted at the trap at the upper end of Chambers Bay; no Chinook are currently passed upstream of the trap (Eltrich, Long, Pers. comm., 2003). Chinook (typically surplus males only) have been passed upstream of the trap sporadically in some past years, but not in recent years. Adult Chinook trap counts are presented in Figure 6. Chinook distribution in WRIA 12 is shown on the Chinook distribution map in the separate Maps file included with this report. The current hatchery Chinook program for Chambers Creek includes releases of 850,000 fingerlings from Chambers Creek Hatchery, 100,000 yearlings from Chambers Creek Hatchery, and 200,000 yearlings from Lakewood Hatchery (Eltrich, Pers. comm., 2003).

Figure 6: Chambers Creek hatchery Chinook trap counts (courtesy of John Long, WDFW)



Chum

A review of Chambers Creek hatchery rack data shows that historically there were two native chum stocks in Chambers Creek, a winter and a summer stock (WDFW and WWTIT 1994). Although the winter chum run remains healthy, Chambers Creek summer chum fit the criteria of an extinct stock. Chum distribution in WRIA 12 is shown on the chum distribution map in the separate Maps file included with this report.

Chambers Creek summer chum were identified as a stock because of geographic isolation from other Puget Sound chum stocks and run timing differences (WDFW and WWTIT 1994). Chambers Creek summer chum first entered the creek around the third week of September, with peak counts around the third week of October. Entry timing was more than two months earlier than the for the Chambers Creek winter chum run, indicating clear temporal difference between the summer and winter stocks. The last observation of summer chum in Chambers Creek was in October 1983, when a total of three chum were observed. There are no current plans or efforts to reintroduce summer chum to Chambers Creek (Baranski, Pers. comm., 2003).

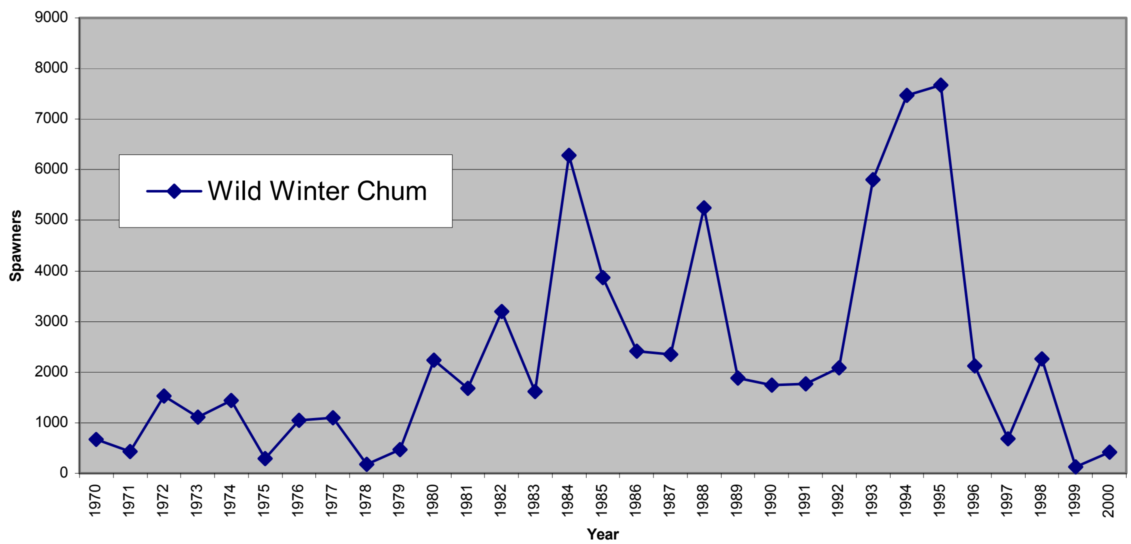
Chambers Creek winter chum are identified as a stock based on their distinct spawning distribution, spawning timing, and genetic composition (WDFW 2003 Draft). Chambers Creek is located near the Nisqually River, which has a large run of native winter chum, but genetic stock identification studies show Chambers winter chum to be similar to, but distinguishable from Nisqually winter chum. Chambers Creek winter chum are a native stock of wild origin. Hoodsport (Hood Canal origin) chum were released from Chambers Creek hatchery in the mid-1980s for a few years. This production was subsequently discontinued. However, a few chum are still observed annually that return in November (Eltrich, Pers.

comm., 2003), prior to the native late-timed chum in Chambers Creek, but no stock identification work has been done to determine whether these are remnants from the earlier hatchery production, are early returning native late chum, or are strays from other South Sound chum stocks. All returning chum are electronically enumerated at the trap, without handling, as they freely pass upstream into the Chambers Creek watershed.

Winter chum stock status is rated as **Healthy** in the 2002 SaSI (WDFW 2003 Draft). The winter chum stock experienced strong escapements from 1980 through 1996 (Figure 7), primarily because of a hatchery supplementation program. The 1997 and 2000 escapements of Chambers Creek winter chum were very low, 677 and 380 spawners respectively, most likely because of the cessation of hatchery releases. This decline was considered as possible evidence of a change to depressed status based on the short-term severe decline stock rating criteria. However, examination of past escapement demonstrates two previous periods with similar levels of escapement on two consecutive years (1969-1970 and 1978-1979). Based on the prior low years, the 1999-2000 escapements likely represent the bottom of the normal low end of the natural spawner escapement range for this stock. Most spawning takes place in a limited part of Chambers Creek (RM 2.4-2.6) and Leach and Flett creeks, generally from January through February.

The extent of chum use in lower Sequalitchew Creek has not been determined. Juvenile chum were

Figure 7: Chambers Creek winter chum salmon escapements (courtesy of John Long, WDFW)



observed in 1971 in the lower several hundred feet of Sequalitchew Creek (Fresh, et al 1979). Williams et al. (1975) speculated that chum may use the lower half mile of Sequalitchew Creek and possibly upstream to Edmond Marsh, ~1 mile above tidewater. No chum stock assessment has been done for Sequalitchew Creek, and the relationship of Sequalitchew Creek chum to Chambers Creek or Nisqually River chum stocks has not been determined.

The Puyallup Tribe has also been planting chum juveniles in Puget Creek but have yet to see a returning adult (Blake Smith, Pers. comm., 2003). It is doubtful whether adult chum are able to effectively migrate upstream. The Puget Creek Restoration Society is working on passage issues in the creek in order to facilitate upstream passage for chum, Coho, and cutthroat.

Pink

Low numbers of pink salmon are periodically observed at the Chambers Creek rack, and are passed upstream of the rack (Eltrich, Pers. comm., 2003). No assessment work has been conducted to determine the origin of returning adult pink salmon to the Chambers Creek rack, and they are not recognized as a stock in the Salmonid Stock Inventory (WDFW 2003 Draft). There are no observations of pink salmon in Sequalitchew Creek, although no regular monitoring has been conducted.

Coho

Coho salmon utilize, to some degree, almost all of the accessible areas in the Puget, Chambers, and Sequalitchew creek watersheds. There have been substantial releases of hatchery origin Coho in the Chambers and Sequalitchew watersheds. Prior to its discontinuation in the mid-1990s, ~1.0-1.5 million Coho smolts were released annually from Sequalitchew Creek. Substantial annual plants of fry also occurred historically throughout the Chambers Creek watershed; this program has also been discontinued.

In addition, now defunct netpen programs contributed significantly to adult Coho returns to Chambers Creek, with Fox Island and Sequalitchew Lake origin Coho historically comprising nearly 75% of the adult Coho return to Chambers Creek (WDFW and WWTIT 1994). Monitoring for adipose clipped Coho at the Chambers Creek trap indicated predominantly unmarked Coho in the 2000 return, with increased numbers of adipose clipped Coho in the 2001 and 2002 returns (Eltrich, Pers. comm., 2003).

Stock status for Chambers Creek Coho was rated as **Healthy** in 1992 (WDFW and WWTIT 1994), but has been revised to **Depressed** in 2002 (WDFW 2002 Draft), based on the short-term severe decline in escapement in 1999 through 2001. This stock does not meet the strict definition of a short-term severe decline in escapement because escapement in only one year, 1999, of the most recent five years is at or below the previous low of 285 in 1985 (Figure 8). However, given the low fishery exploitation rates in this time period, total stock productivity was probably among the worst for this stock and a **Depressed** rating is warranted. A marked drop in escapements and run sizes occurred in this and all other South Sound Coho stocks in mid- to late 1990s, largely the outcome of a precipitous plunge in South Sound Coho marine survival rates that started with the late 1980s brood years. Large numbers of hatchery-origin strays, predominantly from the Lake Sequalitchew and Fox Island Net Pen programs, used to contribute to the Chambers Creek natural Coho escapement. Since the elimination of the Lake Sequalitchew program and the closure of the Fox Island facility, total Coho returns to Chambers Creek have decreased dramatically.

The Chambers Coho stock is a mixed stock with composite hatchery and wild production (WDFW 2002 Draft). Coho distribution in WRIA 12 is shown on the Coho distribution map in the separate Maps file included with this report. There are no significant differences in timing or any unique biological characteristics documented for this Coho stock. The distinction of this stock from those in surrounding drainages is dependent upon a determination of geographic spawning separation, the result of subjective judgments regarding the probability of significant spawner interchange between drainages (WDFW and WWTIT 1994). It is possible that this stock is not distinct from other deep South Sound Tributary Coho, as a result of hatchery releases and straying of hatchery fish. This stock designation is tentative until a genetic determinant is available and used to evaluate differences in south Puget Sound Coho stocks. There is no stated natural escapement goal for the Chambers Creek Coho stock (WDFW and WWTIT 1994).

There is evidence that a now extinct stock of summer Coho used to return to the Chambers Creek watershed (Baranski, Pers. comm., 2003). Darrell Mills (WDFW 2003) recalls them as a uniformly small fish (~4 lb. mean weight) that returned in August and spawned in August and September. The stock had disappeared by the mid-1980s.[2]

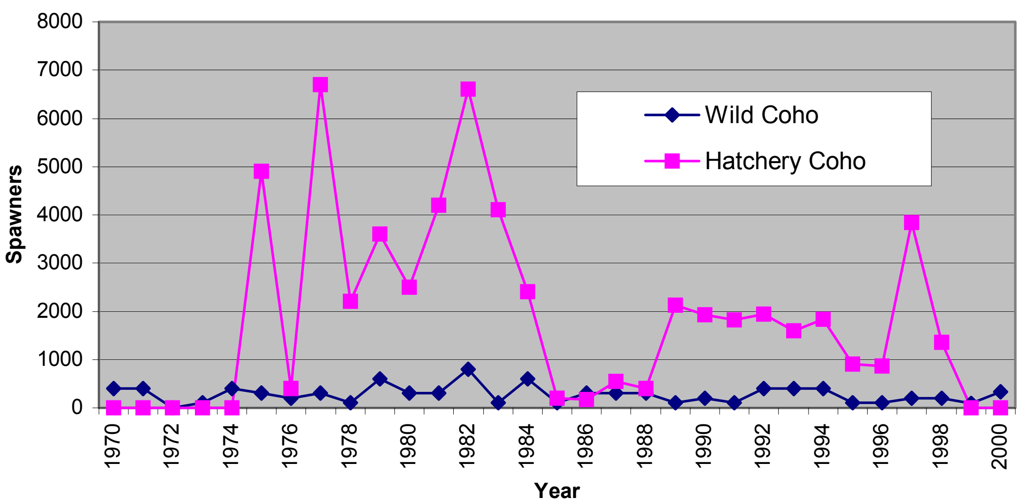
Coho redds and juvenile coho have been observed in Puget Creek (Blake Smith, Scott Hansen. Pers. comm., 2003).

Winter Steelhead

No winter steelhead stock is recognized in either Chambers or Sequalitchew creek (WDFW 2003 Draft). Only a handful of winter steelhead have been observed through the Chambers Creek trap over the last three years of operation (Eltrich, Pers. comm., 2003). However, steelhead were the first salmonids to be captured in the Chambers Creek trap when first operated in 1945 (Crawford 1979), indicating presence of a natural steelhead run. It is possible that steelhead returning to Chambers Creek may pass the dam (trap site) after the trap is opened in early February, and would therefore be undocumented and uncounted. No steelhead stock assessment work has been done in WRIA 12 streams. Steelhead distribution in WRIA 12 is shown on the steelhead distribution map in the separate Maps file included with this report.

The Lakewood Hatchery complex on Chambers Creek was historically used as the primary steelhead spawning site and egg source for much of the western Washington hatchery steelhead program. Adult

Figure 8: Chambers Creek Coho salmon escapements (courtesy of John Long, WDFW)



steelhead were collected at hatchery sites and adult salmonid collection racks throughout western Washington, transferred to the Lakewood Hatchery complex, spawned, and the resulting juvenile steelhead transported back out to streams throughout western Washington. This program has also been curtailed.

Sockeye

There are sporadic observations of returning adult sockeye at the Chambers Creek trap (Eltrich, Pers. comm., 2003).

[2] Pierce County EDT (Mobrand Biometrics, 2001) modeling shows support for a historical run of about 5,000 Coho in the Chambers-Clover Creek System.

A large population of kokanee is present in American Lake. These kokanee are thought to be of Lake Whatcom (Whatcom County) origin, which historically has been the primary source for hatchery kokanee in western Washington (Eltrich, Pers. comm., 2003). Annual releases of hatchery-origin kokanee (predominantly Lake Whatcom stock) into American Lake usually range between 200,000 and 300,000 fry. Tom Cropp (WDFW 2003) has observed spawning kokanee in Murray Creek, tributary to American Lake. Murray Creek is being investigated as a potential local egg-take site for the Puget Sound hatchery kokanee program.

Char (Bull Trout/DollyVarden)

No bull trout/Dolly Varden are known (or expected) to occur in Chambers or Sequalitchew creeks (WDFW 1998). WRIA 12 lacks the high elevation streams and cold water temperatures necessary for bull trout/Dolly Varden spawning and early rearing. The only identified bull trout/Dolly Varden stock south of Tacoma Narrows is in the Nisqually River. Existence of the Nisqually stock is based on observation of only one juvenile bull trout/Dolly Varden by Nisqually tribal biologists in the mid-1980s. No bull trout/Dolly Varden have been reported in Nisqually tribal commercial fisheries, including those that occur in Chambers Bay and on the south Puget Sound shoreline near the mouth of Sequalitchew Creek.

Cutthroat Trout

Sequalitchew Creek cutthroat are included in the Western South Sound Coastal Cutthroat stock complex (Blakley, et al 2000). Chambers Creek cutthroat are conspicuously excluded in the Western South Sound Coastal Cutthroat stock complex, although there is no stated rationale in the Washington State Salmonid Stock Inventory for this exclusion. The exclusion appears to be inadvertent, as both Tom Cropp (WDFW 2003) and Chuck Baranski (WDFW 2003) indicate that cutthroat are present throughout all accessible waters in the Chambers Creek watershed, which is also verified by other documented observations of cutthroat throughout the watershed. Cutthroat distribution in WRIA 12 is shown on the cutthroat distribution map in the separate Maps file included with this report.

The stock status for the Western South Sound Coastal Cutthroat stock complex is indicated as **Unknown** (Blakley, et al 2000). There are no quantitative data on abundance or survival with which to assess status. Hatchery-origin cutthroat were released in the Deschutes River and McAllister Creek for several years. Interbreeding between hatchery and wild cutthroat is thought to have been unlikely because of high catch rates on hatchery fish and poor survival of hatchery-origin fish in the wild. Consequently, Western South Sound coastal cutthroat are considered native; the stock is maintained by wild production.

Cutthroat presence is not recognized in Puget Creek (Blakley, et al 2000). However, cutthroat have been observed in Puget Creek over the past couple of years (PCRS 2002).

Other Species

Resident trout species other than cutthroat are not specifically considered or referenced in this report. These species are present throughout these same watersheds and should also be considered whenever habitat or fish production modifications are considered.

HABITAT LIMITING FACTORS BY SUB-WATERSHED

Introduction

This chapter draws from and complements several key assessment reports that have been completed for all or part of WRIA 12 and the Chambers-Clover Creek Watershed. These documents, compiling available research and information on the condition of salmonid habitat in the watershed, include but are not limited to:

- Chambers-Clover Creek Watershed Management Committee – Watershed Characterization (PCPWU 1997)
- Chambers-Clover Final Draft Technical Assessment (Tacoma-Pierce County Health Department, Clothier, et al 2003)
- Pierce County Clover Creek Basin Plan (Tetra Tech/KCM 2002)

Conditions of the streams of WRIA 12 range from lightly impacted to heavily modified. The range of conditions reflects the variety of land uses found in the watershed, including agriculture, commercial and residential development, and urbanization. Principal impacts have been caused by dredging and rerouting of stream channels, ditching or burying of the stream, elimination of wetlands and estuarine habitat, riparian forest removal, non-point water quality pollution, industrial discharges, fish passage barriers, and removal of large wood from channels.

The first anthropogenic impact in the Clover-Chambers watershed can be traced back to 1853, when Andrew F. Byrd built a dam impounding the waters of a low-lying marsh to power his sawmill, which formed Steilacoom Lake at the headwaters of Chambers Creek (Dallas 1990, cited in Pettit 2000). Later, in the early 1880s, a millionaire from Portland Oregon, Captain John C. Ainsworth, decided to reroute the stream and move it off his property, much of which was flood plain (Nadeau 1983). This pattern of alterations to the stream channel continued. A canal was built in the early 1900s adjacent to the creek to supply the City of Tacoma with drinking water. The canal was never used for its intended purpose but it now carries half of the present creek's flow. The canal is approximately one half mile long and has a gravel bottom. It is located in the area of Old Military Road and 38th Avenue East (Consoer, Townsend 1977 cited in PCPWU 1997).

At some point prior to 1940, probably around 1895 (Tobiason 2003), one mile of Clover Creek between Golden Given Avenue and 138th street was rechanneled into two large irrigation canals to provide water for an extensive hop farming operation. The farm is no longer in operation but the creek still flows within the irrigation channels. Most of the creek flows into the southern-most channel (Consoer, Townsend 1977 cited in PCPWU 1997).

In the 1940s, after McChord Air Force Base was officially dedicated by the federal government, sections of Clover Creek on the base were extensively dredged, channelized, and diked (Consoer, Townsend 1977 cited in PCPWU 1997). In 1938-40, during construction of McChord Army Airfield by the federal government, the sections of Clover Creek on the base were relocated to allow for construction of runways and other facilities. A number of years later, the primary runway was lengthened to approximately twice its original length. The rechanneled creek now flows through two 12 foot-diameter culverts under the McChord runway for 0.6 miles. The culverts are constructed so as not to block water or fish passage (Grenko, 2003).

In the late 1960s the creek from Pacific Avenue to west of Spanaway Loop Road was rerouted into a new channel, which was subsequently lined with asphalt to stem water loss.

Alterations including dredging, pond building, and channel shifting continue to be made throughout the watershed to accommodate increased development in the area. These will be addressed on a stream-by-stream basis later in the document.

Habitat management alone cannot restore salmon populations, but it is a necessary component of recovery (SBSRTC 1999). Degraded conditions in the freshwater, estuarine, and marine environments (and the policies and practices influencing them) can be modified in order to reestablish the natural conditions and processes that shaped salmon evolution. The following habitat management concepts and principles are applicable in all watersheds to restoration of all salmonid species:

- Emphasize protection and reconnection of habitat;
- Use historical information to guide decisions;
- Preserve and restore natural ecosystem processes;
- Use monitoring and assessment to guide adaptive management; and
- Preserve options for the future.

Habitat Elements Included in this Analysis of Salmonid Habitat Limiting Factors by the Washington State Conservation Commission:

Following is a list and description of the major habitat elements used to organize this chapter. Though these elements are often closely related and can overlap, in such a way that one habitat problem could impact more than one limiting factor element, they provide a useful structure to assess habitat conditions within the WRIA. The habitat elements considered in the Water Resource Inventory Area (WRIA) 12 (Chambers-Clover, Sequalitchew Creek watersheds) salmonid habitat limiting factors report include:

<u>Loss of Access to Spawning and Rearing Habitat</u>

This habitat element includes human-placed structures that restrict access to spawning habitat for adult salmonids or rearing habitat for juveniles, including culverts, tide gates, levees, dams, water diversion screening, etc. Additional factors considered are low stream flow or temperature conditions that function as barriers during certain times of the year.

A comprehensive inventory of culverts located within the anadromous accessible waters of this WRIA has not been completed. A limited survey of a portion of Clover Creek was completed by WDFW in 1988, (Whitney memo to Detrick 1988, unreferenced) and the results are included in this report. Most of the remaining data on man-made fish passage barriers cited were derived from Pierce County's Clover Creek Basin Plan (Tetra Tech/KLM 2002).

<u>Floodplain Conditions</u>

Floodplains are relatively flat areas adjacent to larger streams and rivers that are periodically inundated during high flows. In a natural state, they allow for the lateral movement of the main channel and provide storage for floodwaters, sediment, and large woody debris. Floodplains generally contain numerous sloughs, side channels, and other features that provide important spawning habitat, rearing habitat, and refugia during high flows. This habitat element includes direct loss of aquatic habitat from human activities in floodplains (such as filling) and disconnection of main channels from floodplains with dikes, levees, and revetments. Disconnection can also result from channel incision caused by changes in hydrology or sediment inputs.

Channel and Substrate Conditions

The channel habitat element addresses instream habitat characteristics such as bank stability, pools, and large woody debris that are not adequately captured by other designated habitat elements. Changes in these characteristics are often symptoms of other habitat effects elsewhere in the watershed, which should also be identified in the appropriate habitat element discussion (sediment condition, riparian condition, etc.).

Changes in the input of fine and coarse sediment to stream channels can have a broad range of effects on salmonid habitat. Increases in coarse sediment can create channel instability, increased bank erosion, and reduce the frequency and volume of pools. Decreases in coarse sediment transport (e.g., downstream of a dam) can limit the availability of spawning gravel and result in channel incision. Increases in fine sediment can fill in pools, decrease the survival rate of eggs deposited in the gravel, and lower the production of benthic invertebrates. This habitat element addresses these and other sediment-related habitat effects caused by human activities throughout a watershed. These human activities include or result in increases in sediment input from landslides, roads, agricultural practices, construction activities, and bank erosion; decreases in gravel availability caused by dams and floodplain constrictions; and changes in sediment transport brought about by altered hydrology and reduction of large woody debris.

Riparian Conditions

Riparian areas are the land areas adjacent to streams, rivers, and nearshore environments that interact with the aquatic environment. This habitat element addresses factors that limit the ability of native riparian vegetation to provide shade, nutrients, bank stability, and a source for large woody debris. Adverse effects to riparian condition result from timber harvest, clearing for agriculture or development, construction of roads, dikes, or other structures, and direct access of livestock to creek channels.

Water Quality

Water quality factors addressed by this habitat element include temperature, dissolved oxygen, and toxics that directly affect salmonid production. Turbidity is also included, although the sources of sediment problems may also be discussed in the substrate condition habitat element. In some cases, fecal coliform bacteria problems are identified because they may serve as indicators of other effects in a watershed, such as direct animal access to streams.

Water Quantity

Changes in flow conditions can have a variety of effects on salmonid habitat. Decreased low flows can reduce the availability of summer rearing habitat and contribute to temperature and access problems, while increased peak flows can scour or bury spawning nests. Other alterations to seasonal hydrology can strand fish or limit the availability of habitat at various life stages. Storm water runoff from impervious surfaces, or increased exposure to rain-on-snow events, increase the frequency and magnitude of peak flow events, affecting the stability of the creek and associated habitat. All types of hydrologic changes can alter channel and floodplain complexity. This habitat element considers changes in flow conditions brought about by water withdrawals, the presence of roads and impervious surfaces, the operation of dams and diversions, alteration of floodplains and wetlands, storm water runoff from impervious surfaces, and a variety of land use practices.

Estuarine and Nearshore Habitat

This habitat element considers habitat effects that are unique to estuarine and nearshore environments. Estuarine habitat includes areas in and around the mouths of streams extending throughout the area of tidal influence. These areas provide especially important rearing habitat for Chinook, chum, and other salmonid species, and provide for critical adult and juvenile salmonid osmoregulatory adjustment between freshwater and saltwater. Effects to estuarine/nearshore habitat have resulted from loss of habitat complexity due to filling, diking, log raft storage, and channelization; and loss of tidal connectivity to small stream mouths or off-channel wetlands caused by tidegates. Nearshore habitat includes intertidal and shallow subtidal saltwater areas adjacent to land that provide migration and rearing habitat for adult and juvenile fish. Important features of these areas include eelgrass and kelp beds, cover, large woody debris, spawning habitat for forage fish, and the availability of prey species for juvenile salmonids. Impacts include bulkheads, overwater structures, filling, dredging, contamination with industrial chemicals, and alteration of longshore sediment processes.

Lake Habitat

Lakes can provide important spawning and rearing habitat for salmonids. This habitat element considers effects typical to lake environments, such as the construction of docks and piers, increases in aquatic vegetation, and the application of herbicides to control plant growth.

Biological Processes

This habitat element considers impacts to fish brought about by the introduction of exotic plants and animals, and also from the loss of ocean-derived nutrients caused by a reduction in the amount of available salmon carcasses. The intent is to restore ocean-derived nutrients to freshwater streams through the restoration of healthy viable natural spawning populations of anadromous salmonids. Freshwater streams may be currently deficient in marine derived nutrients due to low spawning returns or habitat problems that limit fish utilization or productivity. There are few specific locations where there is information sufficient to characterize the extent to which lack of marine derived nutrients may be a limiting factor for salmonid production.

Watershed Discussions

Watershed discussions are presented for those streams in WRIA 12 that support anadromous salmonids (and bull trout/Dolly Varden), and generally follow the WRIA 12 stream index numbering sequence presented in Williams, et al (1975). Streams without index numbers in Williams, et al (1975) are assigned numbers in accordance with the Stream LLID system, currently in use by WDFW, which is based on the longitude and latitude of the stream mouth. Location clarification for streams with LLID numbers is noted in the text.

Where information is available, the habitat description is contrasted to historical conditions known to have supported greater natural salmonid production. A list of salmonid habitat action recommendations is included at the end of each watershed section; these action recommendations have been reviewed by the TAG and reflect which habitat protection/restoration actions are likely to benefit salmonid production to the greatest extent within the watershed. The action recommendations are based on collective scientific opinion of salmonid production benefit and do not necessarily consider feasibility, landowner interest, or cost, and do not include any prioritization between watersheds. These additional elements should be considered in the development and implementation of the salmonid restoration strategy for WRIA 12.

WRIA 12 Marine Nearshore

General

The WRIA 12 marine nearshore extends from the Tacoma Old Town area east of Puget Gulch, around Point Defiance, then south to the north end of the Nisqually River delta (Williams, et al 1975). In the northwest portion of the watershed, steep bluffs border Puget Sound intersected by deep canyons, accompanied by steeply rolling hills and valleys. The two primary tributaries along this shoreline are Chambers Creek and Sequalitchew Creek. Both of these creeks have estuarine areas that are discussed in the individual creek discussions that follow. Also included in the marine nearshore area of WRIA 12 is the Ketron island shoreline.

Much of the shoreline habitat has been compromised by fill associated with the historic construction of railroads. The most significant estuarine habitat is found in Chambers Bay. A detailed investigation of the water quality, hydrology, and biology of the marine environment of Puget Sound shoreline of the Chambers-Clover Creek Watershed was conducted by Northwest Consultant Oceanographers (NCO) for the Environmental Impact Statement of the Chambers Creek Utilities Local Improvement District (ULID 73-1, 1975 cited in PCPWU 1997).

A comprehensive nearshore assessment has not been performed for the WRIA 12 coastline.

Action Recommendations

The following salmonid habitat restoration actions are recommended for the WRIA 12 nearshore:

- ◊ Conduct a comprehensive nearshore assessment for WRIA 12 habitat.
- ◊ Study current status of eelgrass beds and protect eelgrass habitat.
- ◊ Reduce and minimize shoreline armoring.
- ◊ Control point and non-point sources of contamination throughout WRIA 12.
- ◊ Restore, enhance, or protect viable habitat that provides connective corridors between riverine and estuarine habitats and between estuarine and open water.
- ◊ Consult the Northwest Consultant Oceanographers' study for results in order to develop further recommendations.

Chambers Creek 12.0007

General

Chambers Creek is an independent tributary entering the east shore of Puget Sound between the City of Steilacoom and the south end of Tacoma Narrows (Williams, et al 1975). Chambers Creek extends from the mouth 4.1 RM upstream to the outlet of Steilacoom Lake. Upstream of Steilacoom Lake, the primary tributary is known as Clover Creek, although the river mile designations in Williams, et al (1975) are continued upstream from Chambers Creek. The Chambers Creek watershed drains an estimated 30 square miles (19,200 acres).

Fish Access

At the mouth of Chambers Creek, a dam exists as a complete barrier to all migrating fish. Fish present at the dam are collected by WDFW and either released upstream for spawning or taken to Garrison Springs

Hatchery for egg harvest (Mobrand Biometrics 2001). Coho, chum, steelhead, and cutthroat are currently released upstream for spawning, while returning Chinook are taken to the hatchery.

Chambers-Clover Chinook
Summary Of Projected Performance Measures Under
Status Quo and Expanded Action Scenarios

Scenario	Abundance	Productivity	Diversity index
Historic	1,993	20.4	100%
Current with harvest and fitness loss	67	2.6	41%
Future with status quo mgmt (SQ)	131	3.1	93%
Action Scenario-1 (S-1)	156	3.1	93%
Action Scenario-2 (S-2)	399	4.2	100%
Action Scenario-3 (S-3)	408	4.3	100%
Action Scenario-4 (S-4)	408	4.3	100%

Note:
Abundance is the equilibrium spawning population size.
Productivity is number of spawners produced per parent spawner at low population density.
Diversity index is the percent of life history trajectories modeled that are sustainable (productivity >1)
All future scenarios modeled with the same harvest levels and genetic fitness as currently exists.

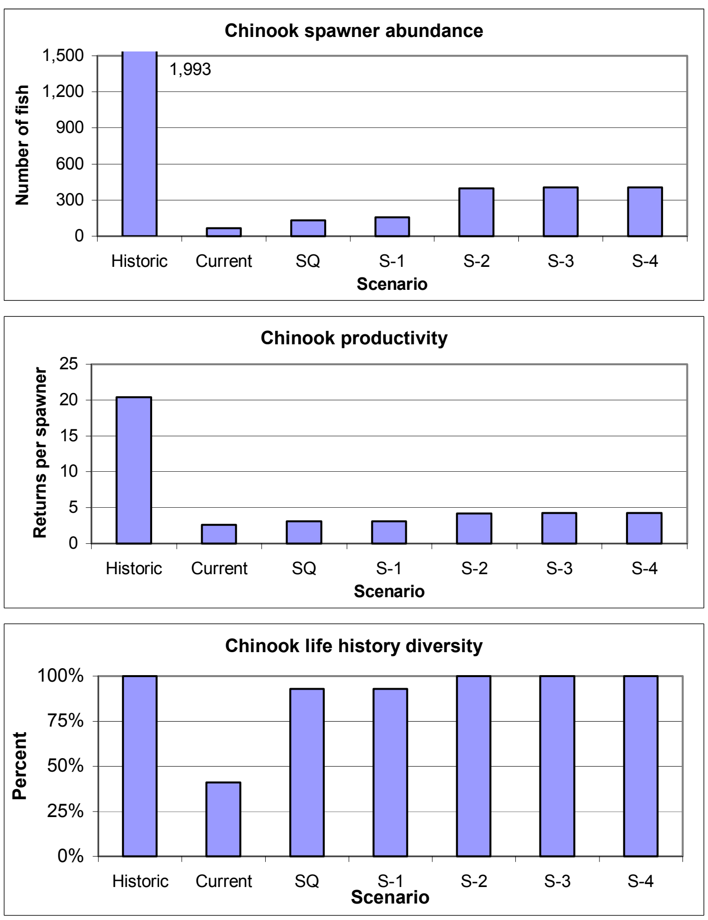


Figure 9: Model of Chinook Production in Chambers Creek (WADSC 2001)

The hatchery practices regarding returning Chinook are based on the belief that WRIA 12 streams do not contain the typical Chinook habitat found in larger Puget Sound river basins. Currently, all adult Chinook returning to Chambers Creek are removed at the rack at the upper end of Chambers Bay, and contribute to the South Puget Sound Chinook hatchery program. Adult Chinook returns to Chambers Creek are considered to be the result of returns from hatchery plants from Chambers Creek or strays from hatchery plants elsewhere in South Puget Sound. If hatchery Chinook production was curtailed in Chambers Creek and elsewhere in Puget Sound, WDFW believes it unlikely that a natural run would persist over time in Chambers Creek (Chuck Baranski, WDFW 2001).

Mobrand Biometrics conducted the EDT study of the Chambers-Clover system, and modeled an historic run of nearly 2000 fish (Figure 9: Model of Chinook Production in Chambers Creek (WADSC 2001)), though they suggested that entry to these small streams would be difficult during drought years. Under current conditions, their model projected the capacity of the system as much less – approximately 70-170 Chinook. At the time of this report, Mobrand is unable to predict the capacity of the system under restored conditions.

The historic role of the smaller, independent streams of Puget Sound in the sustainability and diversity of Puget Sound Chinook runs is a subject still under debate.

No recent comprehensive survey of fish passage barriers has been completed for this creek.

<u>Floodplain Modifications</u>

Much of the instream and riparian (shoreline) habitat of Chambers Creek from Steilacoom Lake to the Leach Creek confluence has been heavily modified by individual homeowners. Many have channelized the stream, armored the stream bank with rocks, and eliminated the vegetation which provides shade and food sources to fish (PCPWU 1997).

<u>Channel and Substrate Conditions</u>

Nearly three decades ago, Williams (1975) observed that Chambers Creek had widths to 25 feet and varied in depth from 6 inches to 2 feet. It contained excellent gravel and good pool-riffle ratios with a moderate gradient. A canyon section from RM 0.5 to 1.75 contained steep hillsides and a narrow confined valley. It generally had all the characteristics of a typical lowland-type stream with stable bank areas.

Because Pierce County owns much of the ravine and has protected it, these observations are still generally true. Dave Renstrom has made recent site visits and notes that the lower section (0.5 miles above the dam) is lower gradient, and much of the streambed is composed of fine sediments (Pers. comm., 2003).

<u>Riparian Condition</u>

The Chambers Creek ravine is part of a natural area and has remained mainly undisturbed. Much of the land area is owned by Pierce County. The ravine and much of the surrounding area was acquired for the purpose of providing parks, sewer services, and road maintenance. Stream reconnaissance during the 1993 site investigation for the Northwest Landing EIS indicated that stream bank cover in the Chambers Creek Canyon area remains excellent, made up of deciduous shrubs and trees along its entire length, with the exception of the lack of vegetation near the mouth of the creek. Although the gradient is steep throughout the lower reach, the streambed is composed of small gravels (2-5 inch), and contains long pool-glide areas separated by short riffle sections. Chambers Creek also has a heavy stream bank cover composed primarily of deciduous trees and shrubs through the canyon area. Shade, which helps maintain lower stream temperatures and promotes good salmonid spawning and rearing habitat, is continuous along the riparian corridor (PCPWU 1997).

According to the Chambers-Clover Creek Management Committee Watershed Characterization (PCPWU 1997), Chambers Creek has more riparian habitat along its length than any other stream in the watershed. Plant species making up this second growth shrub and forest riparian zone include Western red cedar (Thuja plicata), Douglas fir (Pseudotsuga menziesii), Indian plum (Oemleria cerasiformis), Oregon grape (Mahonia nervosa), red elderberry (Sambucus racemosa), and bracken fern (Pteridium aqilinum) (Cited in Clothier, et al 2003).

Upland habitat in the main stem area of Chambers Creek consists of mixed second growth shrub and forest. The area has large portions of relatively undisturbed second growth Douglas fir and Western red cedar. Additional plant species found in these communities were Indian plum, Oregon grape, elderberry, and bracken fern. The main stem supports a rich variety of wildlife species and wildlife use, and is extremely valuable to the public for this purpose (Fries 1994, cited in PCPWU 1997).

Applied Environmental Services, Inc., (AES) completed a study using aerial photos for the Chambers-Clover Technical Assessment Final Report (Clothier, et al 2003), assessing the riparian cover in several streams in WRIA 12. Table 1: Data Summary of Chambers Creek Riparian Corridor summarizes the data collected for Chambers Creek.

Table 1: Data Summary of Chambers Creek Riparian Corridor

	North/East Bank	**South/West Bank**
Approximate Creek Length	25,576 feet	26,697 feet
Percentage of Creek Length with Riparian Cover	24,033 feet 94.0%	19,125 feet 71.6 %
Average Width of Riparian Corridor	268 feet	325 feet
Percent Shade Cover	**76%-100%**	

(Clothier, et al 2003)

Some invasive species have begun to encroach in a few areas. The presence of invasive Japanese knotweed downstream from the Leach Creek confluence has been recently documented by Dave Renstrom (Pers. comm., 2003). In some locations it was noted that the knotweed had established thick stands.

<u>Water Quantity</u>

Both excessive flows and scarcity of water can cause problems. In surface water, too much water can lead to flooding while too little water can cause lakes and streams to dry up and kill the aquatic creatures that depend upon them. Depletion of groundwater resources can threaten municipal water supplies resulting in water rationing and other conservation programs. Low groundwater levels can lead to surface water problems if the springs that supply a stream system dry up.

The interconnected nature of water systems can mean that solving one problem may aggravate another. Efforts to control flooding in winter months can result in low flow problems in the summer and fall. Efforts to keep poor quality runoff and groundwater from reaching creeks may also exacerbate low flow problems. Alternatively, low creek flows may prevent the system from being flushed with clean water as it may have done in the past (PCPWU 1997).

In the Tacoma – Pierce County Chambers-Clover Management Plan Technical Assessment, Clothier, et al (2003) stated:

> The result of a comparison of historic Chambers Creek flows to the current flows is quite interesting, when considered in light of the following watershed changes:
>
> - Modifications to drainage in the WRIA which occurred in the 1950s with major flood control works at and downstream of the outlet of American Lake (lowered American Lake high levels and the regional ground water table elevations)
>   [Note: though American Lake is in the Sequalitchew watershed, groundwater and aquifer connections affect conditions in the Clover-Chambers watershed.]
> - A regional sewer system that diverted water directly to Puget Sound and began operation in 1986 (ULID #1)
> - Increases in the amount of impervious surface
> - Increased use of waters from nearly one-third of the WRIA
>
> All these actions resulted in the general lowering of the regional water table during average and low rainfall years. The importation of Green River water to supply all or part of several WRIA 12 sub-basins for municipal purposes is considered neutral with regard to the regional water table, since the major area served by this imported water is also served by regional sewer systems that export return-flow water from the basin.

Low Stream Flows:

Low summer flows can be highly detrimental to area wildlife. This includes those animals that depend upon the stream as a source of drinking water as well as fish. In addition, a number of insect species depend upon streams during their reproductive process by laying eggs on streamside rocks. This allows their larvae to develop in aquatic conditions. Low flows remove this resource (PCPWU 1997).

Low stream or lake levels can also be a determining factor in which types of riparian species survive. On the shoreline of Carp Lake in southwest Lakewood, for example, invasive reed canary grass has choked out the native species (Diane Dumond, Pers. comm., 1996, cited in PCPWU 1997). Reed canary grass adapts more readily to existing conditions than do the native species at the lake (PCPWU 1997).

A report from Ecology (May 1995) reported that despite closures to further surface water rights, current summer flows are extremely low and cannot adequately satisfy existing water rights, support fish populations, provide recreation and reduce the effects of pollutants (Cited in PCPWU 1997). Lower surface water levels, along with higher water temperatures, unstable streambeds, physical barriers, poor water quality, and extensive development have degraded the suitability of riparian habitat in many parts of the watershed. Rapid decreases in water level are sometimes seen, which can strand fish and expose them to predation. Seven day low flows in Flett and Leach Creeks, the major tributaries of Chambers Creek, have decreased severely in recent years (Ecology, March 1995, cited in PCPWU 1997). Lack of instream flow in Leach Creek has been cited as the main reason that there are no longer any early run Coho or chum runs in that stream (Brad Caldwell, Pers. comm., Jan. 22, 1996). The Department of Ecology estimates that Leach Creek at 40th Street needs a minimum base flow of 1.5 cfs. However, others contend that 0.7 to 1 cfs is sufficient and there will be enough water to support both resident and anadromous fish (Paul Bucich, Pers. comm., Jan. 18, 1996). This issue is significant since the City of Tacoma is required by Ecology to maintain base flow from the City's water supply, in order to mitigate for the loss of groundwater flow coming from the area of the Tacoma Landfill, which has been redirected for contaminant removal (PCPWU 1997).

Clover Creek, the major tributary to the Chambers Creek basin, suffers from both severe flooding problems and from low (often nonexistent) summer flows. This creek has a long history of alterations to its flow patterns. Reports state that the Clover Creek basin is believed to have had perennial flows until the 1930s, and now has intermittent flows. (For a further discussion of this, see the Water Quantity discussion under Clover Creek.) Over the years people have altered the flow of Clover Creek by constructing irrigation channels, asphalt-lined ditches, culverts, creek-fed ponds, concrete slabs, and dredged/diked portions of the creek. There are currently at least 15 creek-fed ponds diverting water from the eastern portions of the creek. These ponds were constructed by adjoining landowners for a variety of purposes including irrigation, fish rearing, storm water control, and aesthetics. It is unlikely that the majority of these ponds have legitimate water rights (Ecology 1986, cited in PCPWU 1997). Water loss and perennial vs. intermittent flows in WRIA 12 are subjects that warrant a deeper level of critical analysis.

More recently, Clothier, et al (2003) stated that the recessional low flows at the Chambers Creek gage below Leach Creek may indicate low flows now on the order of 10 cfs lower than those fifty years ago. This is likely caused by a combination of lowered ground water table conditions stemming from the modified outlet works at American Lake, increased ground water pumping, and possibly area sewering. These factors created a greater capacity in the ground water reservoir to absorb initial and extended rainfall, rather than being discharged as base flow to the creek, as compared to conditions prior to the noted alterations.

Flooding:

There have been flooding problems in certain areas of the watershed. In the North Fork area of Clover Creek, channel capacity limitations (such as undersized culverts) and high surface runoff rates contribute to flash floods, which overwhelm the entire Clover Creek system. Flooding tends to take place in Spanaway Creek from its confluence with Clover Creek upstream to Spanaway Lake. Along the full length of Leach Creek flooding exacerbates channel erosion. Flooding occurs in several locations along Flett Creek (Harold Smelt, PCSWM, Pers. comm., Jan. 24, 1996, cited in PCPWU 1997).

Within the Chambers-Clover Creek watershed, the major flood control structures are infiltration ponds and holding basins. These include Zongas Ponds, Clover Creek Holding Basin, Brookdale Road Gravel Pit, Leach Creek Pond, and Wards Lake Ponds. Seeley Lake performs an important natural function as it detains storm water runoff by serving as both a holding pond and also a filtering wetland (PCPWU 1997).

<u>Water Quality</u>

Water quality factors are included as a limiting factor in this report because they directly affect salmonid production and the health of the stocks in the streams. The following discussion is a compilation of data available for the Clover-Chambers Creek watershed.

In 1981, the Washington State Department of Social and Health Services (DSHS) completed a groundwater survey of Chambers-Clover Creek drainage basin. The survey found coliform bacteria at 29.5% of the groundwater sites sampled (117). In addition, 21.4% of the sample sites exceeded state standards for coliform bacteria at one time or another. The southeast portion of the basin exhibited the highest levels of contamination; coliform was present in 47% of the samples and 38.9% exceeded state limits for coliform levels (Littler 1981, cited in PCPWU 1997).

DSHS also found nitrate and nitrogen levels to be a concern because they were rising from historic levels. In the 1960s, average aquifer levels were approximately 0.5 mg/L, while the 1981 survey found an average of 1.6 mg/L. Eight survey sites were found to have levels of greater than 5 mg/L. The state standard for nitrate-nitrogen in drinking water is 10 mg/L. As a result of these findings, DSHS recommended that a comprehensive geohydrologic study be performed in the basin, ongoing monitoring be initiated, and that Pierce County develop a groundwater management plan for the area (Littler 1981, cited in PCPWU 1997).

Brown and Caldwell performed a comprehensive geohydrologic study on the Chambers-Clover Creek basin in 1985 under the direction of the Tacoma-Pierce County Health Department. The study found that nitrate concentrations in the shallow groundwater had increased by about 40% throughout the basin over the last 20 years. Chloride levels in the shallow groundwater increased 400-500% while deep aquifer chloride levels increased by 50% in the last 20 years. Nitrate and chloride levels were sampled because they are considered to be excellent indicators of contamination from sewage. General water quality degradation, as indicated by increased nitrate and chloride levels, seems to be resulting from high density residential areas using on-site sewage treatment and from storm water drywells. The shallow aquifer is showing the highest level of contamination at this time, while the deep aquifer exhibits limited contamination (Brown and Caldwell 1985, cited in PCPWU 1997).

During the DSHS groundwater survey, three organic chemicals were detected at one sampling site within the watershed just south of the point where Clover Creek passes under Interstate 5 near American Lake Gardens. The organic compounds found included: 1,2 dichloroethylene, tetrachloroethylene, and trichloroethylene. (Littler 1981, cited in PCPWU 1997) Tetrachloroethylene, also known as perchloroethylene (PCE), is a widely used solvent and degreaser, commonly used by drycleaners among others. It affects the central nervous system, is highly volatile, and is not water soluble. Trichloroethylene (TCE) is a common degreasing agent, which is widely used by both industry and households. TCE is highly volatile and poorly soluble in water. TCE attacks the nervous system and has been found to cause liver damage in lab animals. TCE has been shown to be toxic to fish. 1,2-dichloroethylene is a breakdown product of PCE and TCE. The location of these contaminants near McChord Air Force Base may be showing effects related to past military activities such as large scale cleaning operations (Littler 1981, cited in PCPWU 1997). However, it may also be possible that poor practices by a local dry cleaner may have contributed to the contamination. Identification of these substances in groundwater prompted efforts to provide an alternative supply of drinking water to residents within the American Lake Garden Tract who were being served by private wells. A substantial environmental cleanup effort was also instigated by the EPA, the U.S. Army, and the U.S. Air Force. Two scrubbing towers were installed near 1-5 to remove these compounds from a localized groundwater contaminant plume. Groundwater treatment plants are also in operation on McChord Air Force Base and Fort Lewis Army Post to clean up groundwater contamination (Grenko, Pers. comm., 2003).

Table 2: Surface Water Quality Standards for Washington Class A Waters

Fecal Coliform	< 100 organisms/100 ml
Dissolved oxygen	> 8.0 mg/L
Temperature	<18.0° C
pH	6.5-8.5
Nitrogen	< 0.32 mg/L*

*U.S.E.P.E. "Water Quality Criteria 1972." (March 1973)
Data taken from table in Chambers-Clover Basin Instream Resource Protection Program, Washington Department of Ecology, 1979.

Hallock & Hopkins (1994) reported that the Department of Ecology performs monthly ambient monitoring in Chambers Creek below Lake Steilacoom. Temperature levels for the creek were in compliance with WAC 173-201A standards (Table 2: Surface Water Quality Standards for Washington Class A Waters) and the average water temperature was found to be 11.7°C. Dissolved oxygen levels also met state standards with an average dissolved oxygen level of 10.5 mg/L. Total dissolved gas levels for the creek exceeded the state maximum of 110% on two occasions in August and September of 1993 when levels of 117.3% and 116.7% were recorded. Measures for pH were also in compliance with standards with one exception, the average pH being 7.6. One pH reading of 8.9 was taken from the creek in March of 1990, which exceeds the state maximum pH level of 8.5 for a Class A stream. Turbidity levels within the creek were not in compliance with WAC 173-201A standards on one occasion in September of 1989 when turbidity levels reached 42 NTU. The average turbidity level for the creek is 2.6 NTU. Turbidity cannot increase by more than 5 NTU over background levels without violating state standards. Fecal coliform counts in the creek consistently failed to meet the state standard maximum count of 100 organisms/100ml with an average count of 223 organisms/100ml. Samples taken from the creek ranged between 2 and 7100 organisms/100ml. Nitrogen levels in the creek were fairly moderate with total nitrogen levels averaging 1.2 mg/L and total phosphorous levels averaging 0.06 mg/L (Cited in PCPWU 1997).

The USGS (1996) found that pollutant loads in the Clover Creek basin tended to be lower in areas with highly permeable soils, such as the lower portion of the basin. The USGS also reported that several lakes (e.g., Spanaway, Tule) in the Clover Creek basin appeared to improve downstream water quality by serving as pollutant “sinks”. In contrast, Steilacoom Lake appears to have contributed to elevated copper concentrations in Chambers Creek. Copper sulfate was used to control algae growth in the lake for many years (KCM 1996, cited in Clothier, et al 2003).

Pierce County summarized most of this data in a 1997 report: Available data indicates that Chambers Creek has generally met state standards for temperature, dissolved oxygen, and (except on one occasion) pH. Turbidity levels have exceeded state standards on occasion. Fecal coliform counts in the creek averaged 223 colony forming units (cfu)/100 ml and ranged as high as 7,100 cfu/100 ml – well above the state standard of 100 organism/100 ml. Total nitrogen levels averaged 1.2 mg/L, and total phosphorous levels averaged 0.06 mg/L (PCPWU 1997).

The Chambers-Clover Creek system is often subjected to a peak in turbidity in early fall, which may be attributed to storm water runoff occurring at the beginning of the rainy season and a subsequent flushing of built up pollutants into the system. These first flush conditions generally occur in September. (A first flush is a rain event that occurs after an extended period of little or no rainfall. In these instances, the rain washes pollutants off surfaces where they have been collecting during the dry period. Storm water runoff typically contains higher concentrations of pollutants during first flush events) (PCPWU 1997).

Water quality problems in Clover Creek, the headwaters of Chambers Creek, gained the attention of the media on December 2, 1993 when about 40 adult Coho salmon died after attempting to swim up Clover Creek following the first heavy rain of the season. Reports were made of oddly colored storm water discharges entering the creek upstream of the fish kill. Although samples were taken, no conclusive evidence was found to determine the cause of these deaths (Shields 1993, cited in PCPWU 1997). (For detailed report, see newspaper article, Appendix D.)

<u>Lakes</u>

Waughop Lake is located in Fort Steilacoom County Park in the southern portion of this sub-watershed. The lake covers about 33 acres and has a maximum depth of 14 feet. The only connection between this lake and the Chambers-Clover Creek system is through underground aquifers.

Estuarine

The Chambers Creek Estuary historically extended approximately 6000 feet upstream from the Puget Sound entrance. Its initial width, beyond a narrow 200 foot wide mouth, is 1200 feet. The estuary narrows and remains 400 to 600 feet wide by the time it reaches 1000 feet inland. A dam has been placed 4000 feet upstream. The estuary now stops at the dam. Silt deposits are no longer free to flow into the estuary in Chambers Bay, but now deposit upstream of the dam (Renstrom, Pers. comm., 2003).

Prior to 1971, the benthic deposits in Chambers Bay reportedly had organic contents to 50% and high concentrations of hydrogen sulfide. The contents were the result of settled bark and leachates due to logging activities, which have been relocated outside Chambers Bay. Log rafting has not been practiced on the Bay since the early 1970s. Habitat conditions in the estuary have improved significantly since these changes occurred (Mills, Pers. comm., 1994, cited in PCPWU 1997).

The marine and estuarine portions of Chambers Bay below Chambers Creek provide a sand and silt substrate for marine intertidal organisms. This type of habitat can normally support abundant numbers of clams (Bivalvia), small crustaceans (eg. Amphipoda), and annelid worms (eg. Oliaochaeta and Polychaeta) (PCPWU 1997).

Action Recommendations

The following salmonid habitat restoration actions are recommended for the Chambers Creek watershed:

Fish Access:

- ◊ Conduct comprehensive fish passage barrier and priority index survey.
- ◊ Remove or replace identified high priority salmonid-blocking culverts, dams, weirs or other blockages with fish-friendly alternatives.

Floodplain Modifications:

- ◊ Work with residents in the Chambers Creek watershed to improve floodplain and riparian conditions.

Channel/Substrate:

- ◊ Restore stream to more natural system (sinuosity, habitat complexity, sediment delivery, etc., where possible throughout the stream.
- ◊ Increase channel complexity by addition of instream large woody debris (LWD) in appropriate areas.

Riparian:

- ◊ Maintain and protect existing functional riparian vegetation.
- ◊ Encourage landowners to restore degraded riparian conditions through education and regulation. Use historic information and on-site surveys to restore with the appropriate native plant species, and consider the stream size for a functional riparian buffer.
- ◊ Eliminate non-native plants from riparian zones, and revegetate with native species.
- ◊ Reduce riparian wood removal, including removal by private citizens, through education and regulatory actions.

Water Quantity:

- ◊ Protect and maintain areas that are important for aquifer recharge.

◊ Seek opportunities to reduce water withdrawals from the drainage.
◊ Follow recommendations that are beneficial to salmonids that develop from the Watershed Planning (2514) process.

Water Quality:
◊ Reduce industrial and urban pollution inputs, including storm water run-off, into the drainage.
◊ Conduct study of the impact of the first flush phenomenon in association with storm water runoff in high density, urban areas, on the quality of water in the drainage.
◊ Improve water quality throughout the Chambers Creek drainage by addressing the riparian, instream flow, and wetland loss conditions. These are further described in their respective sections.
◊ Address failing septic systems throughout the drainage.
◊ Implement agriculture's Best Management Practices to reduce nutrient runoff and livestock waste delivered to streams in the upper part of the creek drainage (esp. Clover Creek).

Estuarine:
See the previous section on WRIA 12 Marine Nearshore for all Estuarine Action Recommendations.

Clover Creek 12.0007
NF Clover Creek 12.0014, Unnamed 12.0015

General

Clover Creek is the upstream extension of Chambers Creek, including and extending upstream from Steilacoom Lake (Williams, et al 1975). The Clover Creek watershed drains an estimated 74 square miles (47,360 acres) (Tetra Tech/KCM 2002). The North Fork of Clover Creek is a right bank tributary draining the Summit area. It is 3.2 miles long (Brown & Caldwell 1985, cited in PCPWU 1997) and enters Clover Creek at ~RM 12.25 (Williams, et al 1975). Unnamed 12.0015 is a right bank tributary, 2.3 miles in length, entering NF Clover Creek at ~RM 1.0.

Fish Access

Although some accounts equate the construction of the Byrd mill site below Steilacoom Lake to the loss of native salmon runs in the upper basin, this first dam on the creek may not have been an impediment to the migration of anadromous fish. This theory is supported by the fact that the creek continued to support strong runs of sockeye, summer chum, early and late Coho, and Chinook salmon until quite recently. Additional evidence indicates that passage beyond the structure was maintained prior to and after 1949, when the Department of Fish and Game replaced an aging wooden ladder with a new structure. Ironically, the greatest impediment to fish passage occurred when the replacement ladder fell into disrepair in the early 1980s. Six years elapsed before the dysfunctional wooden ladder was replaced with the present concrete structure, quite possibly leading to the elimination of native stocks that until then had returned on 3 to 4 year cycles (Pettit 2000).

Since 1949, barriers in the Clover Creek system hindered salmon migration upstream of Steilacoom Lake, and by 1975, use of Clover Creek by migrating salmon was no longer documented. A dam had been built at the outlet of Steilacoom Lake and provided only intermittent passage into the lake. In the late 1980s, an improved fish ladder was put in place at the dam location to allow fish migration past the dam and upstream of the lake. The ladder operation is still subject to available water flows out of the lake and flow manipulation by the Steilacoom Lake Homeowners Association. This situation is monitored closely for sufficient flows during the salmon upstream migration and spawning window (Rich Eltrich, Pers. comm., 2002). Evidence of successful fish passage using the ladders was not well documented until 1997 when a large run of Coho salmon numbering in the hundreds was observed spawning in Clover Creek. WDFW reports that there were some efforts in the 1990s to transport and haul adult Coho into areas upstream of Steilacoom Lake (Rich Eltrich, Pers. comm., 2002). The temporary fish ladders at the dam located at the outlet from Steilacoom Lake have been replaced with permanent concrete ladders (Tetra Tech 2000, cited in Clothier, et al 2003).

Many species depend on stream systems for habitat, although they may use the habitat in different ways. Examples include fish use of stream habitat for all or part of their life cycle, terrestrial species that utilize the stream for drinking water, and some insects that depend on the stream for the reproductive phase of their life cycle (PCPWU 1997). Low water flow can be detrimental to all of these species. However, low flow can pose a particularly significant problem for fish species due to the potential for stranding. When water levels drop too low, it can create a series of pools that are not connected to each other or separated by dry creek bed. This occurrence traps all the fish present within that reach of the stream in small pools, where habitat and food are limited resources. Stranding has been documented in Clover Creek between 138th St. South and the Brookdale Golf Course (although with a different set of circumstances) (Clothier, et al 2003). Low flows also limit the ability of salmon to reach their historic spawning grounds.

One area providing an example of barrier due to low flows and stranding is located in the Parkland area. Prior to 1940, possibly as early as the 1890s (Tobiason, 2003) a large hop farm was developed within a portion of Clover Creek. This activity caused approximately one mile of Clover Creek between Golden Given Avenue and 138th Street to be re-directed into two large irrigation channels, one on each side of the farm. These two channels still function today with a large wetland existing in between. The northern channel sits at a higher elevation than the wetland and the southern channel, so when water levels rise, the water spills over into the wetland. As fish smolts migrate downstream, they follow the flow of water into the wetland. Consequently, as water levels eventually recede the fish become stranded in the wetland (PCPWU 1997).

A more severe problem is occurring in Clover Creek east of McChord AFB. During both 2001 and 2002, the creek has gone completely dry during the late summer months between 136th St. So. and Spanaway Loop Road, and also downstream to the marshy area east of the McChord culverts, locally referred to as the Schibig/Smith Marsh. In fact, the stream has been dry several times all the way to Steilacoom Lake, even with the added flow of water from Spanaway Creek (Tobiason, Pers. Comm., 2003).

Figure 10: Clover Creek near C Street bridge, September 2002
(Photo by Pierce Conservation District)

The most recent known survey of Clover Creek for barriers by WDFW was conducted by Ron Whitney (Memorandum from Whitney to Chris Detrick, February 11, 1988, unreferenced). This was only a partial survey. According to the memo, the culverts under the runways at McChord AFB were not measured due to base restrictions. [However, Mike Grenko, (Pers. comm., 2003) reports that base officials verified the diameter of the two culverts as 12 feet, approximately 0.6 miles long]. In addition to the dam at the mouth of Chambers Creek, only one additional man-made dam was found at RM 7.5. Whitney reports: “This dam is 1.4 feet high from the water surface. A good plunge pool here makes this a passable structure.” According to current WDFW standards, however, a structure 1.4 feet high (0.42 m), would be considered a barrier. If the stream is not used by chum salmon, but is used by Coho (as is the case here) and the water surface difference is greater than 0.3 meters, this would be categorized as a barrier (WDFW 2000).

The most complete assessment of culverts in the drainage was completed by TetraTech/KCM for Pierce County. Their findings indicate that most culverts in the Clover Creek Basin were designed and constructed prior to recent state and local regulations that require consideration of fish passage in culvert design. The 2000 stream assessment found that many of these older culverts may be barriers to juvenile passage and possibly adult passage (Tetra Tech/KCM 2002).

Figure 11: A dam created a pond and a barrier to fish
(Photo by Pierce Conservation District)

Figure 12: Weirs now provide access for migrating salmon
(Photo by Pierce Conservation District)

Locations of culverts found to prevent or hinder upstream migration of fish in the 2000 stream assessment include the 138th Street East and Military Road culverts in the main stem, the three Brookdale Road culverts, the Waller Road culvert, and the 30th Avenue East culvert in the North Fork. The following barriers to fish passage identified in previous reports were verified during the 2000 stream assessment:

- The entire length of the reach from Spanaway Loop Road to C Street is a seasonal barrier to fish passage. During the stream assessment in May 2000, only 2 inches of water was flowing over this asphalt-lined reach, and it is likely that fish passage through the reach is limited or prevented from April through October.
- Several concrete weirs are located in the reach immediately upstream of Steilacoom Lake. Three of these weirs are approximately 6 feet high, and fish ladders have recently been constructed to aid in upstream fish migration. These fish ladders are an improvement over previous installations; subsequent projects could ease passage by larger fish such as adult Chinook salmon.

Although Chinook are not currently present, historically the Clover Creek watershed was used by Chinook and sockeye salmon until the mid 1940s.
- The significant site-specific habitat problems in the North Fork subbasin are fish barriers due to raised culverts on Brookdale Road (TetraTech/KCM 2002).

One of the most downstream barriers to fish passage was removed when a dam located just south of Gravelly Lake Drive was replaced with a series of concrete weirs in 2001 (**Error! Reference source not found.** and Weirs now provide access for migrating salmon).

Although the biological effects of passing through 0.6 miles of culverted length with no sunlight on salmon ready to spawn are unknown, the twin 12-foot diameter culverts underneath the McChord Air Force Base runways have not been documented as barriers to passage. Spawning salmon have not been found stacked up at the downstream end of the culverts, as is often seen below blockages. They can often be found upstream from the culverts near the Brookdale Golf Course during spawning season (Marcantonio, Pers. comm., 2003).

<u>Floodplain Modifications</u>

Modification of the Clover Creek floodplain began as early as the mid-nineteenth century. In 1853, Andrew F. Byrd built a dam impounding the waters of a low-lying marsh to power his sawmill, which formed Steilacoom Lake at the headwaters of Chambers Creek (Dallas 1990, cited in Pettit 2000).

Since the late 1800s, Clover Creek has been extensively modified by canals, diversions, channelization, and diking. Several old diversion canals still carry appreciable water. In the early 1900s, a canal was built adjacent to the creek to supply the City of Tacoma with drinking water. The canal was never used for its intended purpose but it now carries half of the present creek's flow. The canal is approximately one half mile long and has a gravel bottom. It is located in the area of Old Military Road and 38th Avenue East (Consoer, Townsend 1977, cited in PCPWU 1997).

Ponce de Leon Creek was the historic, most downstream portion of the Clover Creek channel, immediately upstream from Steilacoom Lake. Much of an alternate western segment of Clover Creek was widened and deepened during the 1930s and early 1940s to help alleviate winter flooding problems. Approximately 4.0 miles of the creek were dredged during this project (Clothier, et al 2003). Prior to construction of the Lakewood Mall, during periods of high flow, Clover Creek would overflow into the historic connection to what is now Ponce de Leon Creek (Consoer and Townsend 1977). The natural channel extending from the McChord western boundary to what is now called Ponce De Leon Creek was abandoned when the present day channel was widened and deepened. The Clover Creek reach within McChord AFB was relocated in 1938-1940 to make way for runway and facility construction (Grenko, Pers. comm., 2003).

At some point prior to 1940 – probably about 1895 (Tobiason 2003) – one mile of Clover Creek between Golden Given Avenue and 138th Street was rechanneled into two large irrigation canals to provide water for an extensive hop farming operation. The farm is no longer in operation but the creek still flows within the irrigation channels. More than half the water volume flows into the southern-most channel. There are a number of small marshes adjacent to the creek in this area (Consoer and Townsend 1977, cited in PCPWU 1997).

Until the late 1960s, Clover Creek flowed through the Pacific Lutheran University campus, and crossed Spanaway Loop Road at around 122nd Avenue. In 1966-67, the excess storm water was diverted through a deeper, wider, asphalt-lined ditch for one and a half miles (Consoer and Townsend 1977, cited in PCPWU 1997) until it reaches more natural conditions west of Spanaway Loop Road.

Figure 13: Large salmon (reported as Coho) and trout caught in Clover Creek near Pacific Avenue in November, 1936.
(Photo from the Tom Cambern family album, courtesy of Fred Tobiason.)

More than 15 creek-fed ponds have been constructed in the eastern and central portions of the creek (PCPWU 1997). Few of the ponds have been lined to effectively prevent water loss through the soil. Responsibility for maintaining the ponds rests with the landowners. Few of these ponds were permitted or have established water rights (Ecology 1986, cited in PCPWU 1997).

The North Fork of Clover Creek has been extensively modified due to urbanization and is now little more than a series of deep interconnected roadside ditches. South of Brookdale Road the tributary was dredged and concrete slabs placed along the banks to prevent erosion (Ecology 1986 cited in PCPWU 1997).

In summary, dense residential, commercial, and military development encroaches upon most of the Clover Creek main stem from Steilacoom Lake to the confluence with the North Fork. The same is true of the North Fork of Clover Creek, from the confluence to approximately Brookdale Road, and of Spanaway Creek, from the downstream end of Tule Lake Road to 138th Street East. Low-density residential development and agricultural practices are typically encroaching upon the banks of the Clover Creek main stem upstream of the North Fork confluence. A basin study conducted in 1994 (KCM 1994, cited in TetraTech/KCM 2002) found the following:

- From Steilacoom Lake to McChord Air Force Base, residential development has eliminated most of the riparian area. Very little protection for fish remains, and a lack of shade and filtration media adversely affects water quality in the creek.
- From 136th Street East to Waller Road, encroachment of low-density residential development has encroached on wetlands in the riparian corridor.

- From Waller Road to 160th Street, encroachment of low-density residential and livestock uses is affecting wetlands in the riparian corridor.

Channel and Substrate Conditions

From Gravelly Lake Drive through McChord Air Force Base, much of the instream habitat has been replaced with armored or asphalt channel, including long culverts underneath the McChord runway and beneath I-5. There is little shade or filtration media to protect fish and water quality. Ponds created in this area cause water loss, fish stranding, and may cause flooding (KCM 1993, cited in PCPWU 1997).

From just west of Spanaway Loop Road east into Parkland, the creek runs in an asphalt lined ditch. Volunteers have been placing gravel and stumps into these channels as well as planting trees along the banks. However, this has generated concerns from neighbors and government agencies about the potential for flooding (PCPWU 1997).

Pockets of good spawning ground exist east of “A” Street, but there are also water flow problems. Here and in other places during the summer, the creek is dry because the seal to the creek bed has been broken and the water runs directly into the surrounding gravelly soils or feeds manmade ponds installed by adjoining homeowners. Volunteers have been actively sealing leaks, removing invasive vegetation (usually reed canary grass) from the stream, and planting trees to provide shade to prevent the regrowth of invasive plants. Periodically there is more water upstream than downstream. Significant riparian and headwater wetlands have been altered and filled in the Waller Road area, limiting habitat and flow attenuation. Homes and lawns infringe on riparian habitat throughout this section of the stream and a few small farms allow animal access to the creek in this area.

The headwaters of Clover Creek are not accessible to fish but would not provide good spawning habitat because the streambed is lined with silt rather than clean gravels. (PCPWU 1997)

Erosion in this watershed is generally slight to moderate. Most of the channel gradients above Chambers Creek are relatively flat. The principal source of sediment is from new construction, generally for new homes being built on the rolling uplands adjacent to Clover Creek. The natural soil is loosened and churned by construction machinery during the removal of the forest, and excavation for basements and other foundations. Winter rains erode this loose soil seriously. Considerable refuse and debris which has been discarded by the general public and cast into the Clover Creek channel floats down the channel during periods of high water (SCS&FS 1970). Much of this debris is caught in the marshy area at the east side of McChord AFB (Tobiason, Pers. Comm., 2003), but that which makes it through usually ends up in Steilacoom Lake.

Riparian Condition

Soule (1991) documented a decade ago that much of the habitat in the Chambers-Clover Creek Watershed was confined to small areas and subject to fragmentation (Cited in PCPWU 1997).

More recently, in a study for the Tacoma-Pierce County Health Department, Clover Creek was found to have a wide variation in riparian zone width from reach to reach. The headwaters region was found to have more riparian cover than near the mouth at Steilacoom Lake. This was expected, since much more urban development exists near the creek mouth at Steilacoom Lake (PCPWU 1997).

Overall, much of Clover Creek was found to be degraded and altered from its natural state. Despite this degradation, the percentage of creek length with riparian cover is high. This may be due to the region near the headwaters of Clover Creek having minimal urban development. The lower half of the creek has been channelized and culverted through McChord AFB and much of the stream-side vegetation has been removed in other areas. AES determined shade cover to be 26% to 50% due to urban development and vegetation removal along the creek (Table 3: Data Summary of Clover Creek Riparian Corridor).

Table 3: Data Summary of Clover Creek Riparian Corridor

	North (East/West) Bank	South (West/East) Bank
Approximate Creek Length	68,758 feet	68,758 feet
Percentage of Creek Length with Riparian Cover	41,452 feet 60%	37,686 feet 55%
Average Width of Riparian Corridor	199 feet	351 feet
Percent Shade Cover	**26%-50%**	

(Clothier, et al 2003)

The lack of woody stream bank vegetation has caused many problems in the watershed. The absence of shade increases stream water temperatures and promotes the establishment of invasive plant species such as elodea and reed canary grass. Both of the plant species have adverse effects on stream conditions by slowing flow, decreasing dissolved oxygen, and decreasing biological diversity in the riparian areas (PCD, 1998).

Figure 14: Reed canary grass chokes the stream channel
Photo taken on Clover Creek Reserve near 141st Street South.
(Photo by Pierce Conservation District)

Beginning at the most downstream reach of the basin, the riparian zone around Steilacoom Lake has been eliminated by development up to the edge of the banks. Existing vegetation consists of non-native ornamental shrubs and grass (TetraTech/KCM, 2002).

The bank of Clover Creek from its entry into Steilacoom Lake up to Gravelly Lake Drive has good tree coverage but the habitat is impacted in other ways. While overstory vegetation remains, much of the low growing and stream bank vegetation has been replaced by English ivy from the mouth to approximately 3000 feet upstream. The ivy was planted by local residents and helps to stabilize the bank but it is invasive and has out-competed species which provide better and more varied food sources to riparian wildlife. There are no plans to remove the ivy at this point in time. Concrete sacks were placed along the banks as part of a historic Civilian Conservation Corps project in the 1930s and the ivy now covers most of them (PCPWU 1997).

From Gravelly Lake Drive to McChord Air Force Base, much of the riparian habitat has been replaced with armored or asphalt channel. There is little shade or filtration media to protect fish and water quality (KCM 1993 cited in PCPWU 1997). Increased and more varied vegetative cover would improve habitat conditions in this area (PCPWU 1997). Pierce County reported the elimination of most of the riparian area in Clover Creek between Steilacoom Lake and McChord Air Force Base as a result of residential development (TetraTech/KCM 2002), though it has been reported that the riparian cover in this area fares better than that in the reach east of McChord AFB (Whitman, Pers. comm., 2003).

Citizens groups have been replanting riparian and buffer areas in the reach of the main stem of Clover Creek between McChord Air Force Base and 136th Street (TetraTech/KCM 2002).

Historical agricultural and livestock use of the upper sections of the reach between 136th Street South and Waller Road has destroyed riparian areas and supported invasion of non-native species such as reed canary grass. The Clover Creek Council is placing weed barrier material and planting riparian vegetation west of Waller Road (TetraTech/KCM, 2002).

Significant riparian and headwater wetlands have been altered and filled in the Waller Road area, limiting habitat and flow attenuation. Homes and lawns infringe on riparian habitat throughout this section of the stream and small farms allow animal access to the creek in this area (PCPWU 1997).

On the main stem of Clover Creek, Pierce County found that the problem of livestock access exists only between the Brookdale Golf Course and 152nd Street East . On the North Fork of Clover Creek, the problem is concentrated in the upper portions of the tributary, upstream of 30th Avenue East (Waller Road), where the North Fork splits into several ditches. The ditches flow through pastureland where cows were observed in the stream (TetraTech/KCM 2002).

The headwaters of Clover Creek are characterized by forested and emergent wetlands, which provide good wildlife habitat. These areas are not accessible to fish but would not provide good spawning habitat because the streambed is lined with silt rather than clean gravels (PCPWU 1997).

The North Fork of Clover Creek was found to have significant development along its bank, resulting in a low percentage of creek length with riparian cover (
Table 4: Data Summary of the North Fork Riparian Corridor).

Table 4: Data Summary of the North Fork Riparian Corridor

	North/West Bank	**South/East Bank**
Approximate Creek Length	16,949 feet	16,949 feet
Percentage of Creek Length with Riparian Cover	5,868 feet 34.6%	7,154 feet 42.2%
Average Width of Riparian Corridor	191 feet	219 feet
Percent Shade Cover	**26%-50%**	

(Clothier, et al 2003)

Percent shade cover was determined to be 26% to 50% due to urban development and vegetation removal along the creek.

In summary, most of the riparian issues are endemic and apply to most of the Clover Creek watershed. Lack of riparian vegetation is a problem throughout the majority of the stream reaches in the subbasin. English ivy has become an invasive problem along the banks of the lower reaches of the stream, while invasive colonies of reed canary grass are the dominant plant species in many other areas. Reed canary grass growing in the channel decreases channel capacity and increases sedimentation (TetraTech/KCM, 2002).

Water Quantity

Clover Creek suffers from both severe flooding problems and from low (often nonexistent) summer flows. In 1977, Pierce County adopted the Clover Creek Basin Drainage Plan to address flooding problems in the subbasin.

In response to concerns about the lack of water flow in portions of Clover Creek, in August of 1984, the Washington State Department of Ecology undertook an investigation to identify the causes and possible solutions for intermittent flow. In 1986, the Department of Ecology issued a document called "Intermittent Flow On Clover Creek: Causes and Possible Solutions" in an effort to address low flow issues on the creek (PCPWU 1997). An excerpt from this investigation is available in Appendix C.

They determined that through time, silt and organic debris accumulated on the gravel bed of Clover Creek to form a natural seal that inhibited seepage. Up until the late 1800s, this fragile seal remained intact, and the creek flowed perennially. Since then, dredging, rechanneling, and other modifications to the creek channel caused disruption of this seal. The cumulative effect of such modification was readily apparent by the early 1940s, when Clover Creek ceased to flow year round through its central 3.15 miles. A number of pump diversions and the construction of more than 20 creek fed ponds throughout the basin since the 1940s further aggravated the problem (Sinclair and Carter 1990).

Tetra Tech (2000) reported that until the late 1800s, Clover Creek flowed year-round mostly due to a silt, organic debris, and gravel bed that formed a stream-bed seal preventing seepage. Beginning sometime after 1880, dredging, channeling, and relocation of the creek throughout this subbasin has contributed to intermittent flows and water loss (TetraTech/KCM 2002).

Figure 15: A view of Clover Creek, looking west
(Photo from the Tom Richards family, 1940; courtesy Fred Tobiason)

A study recently completed by Fred L. Tobiason suggests that Clover Creek was subject to perennial flows from the late 1880s to around 1940 (Tobiason 2003), whereas some earlier documents suggest that intermittent flows began in the late 1800s. An extensive series of interviews with residents along Clover Creek during the time period encompassing 1924-1940 showed that Clover Creek flowed continuously during that period. There were many eyewitness reports of significant steelhead and salmon runs (see Figure 13: Large salmon (reported as Coho) and trout caught in Clover Creek near Pacific Avenue in November, 1936.), as well as native and searun cutthroat. One of the residents, Tom Richards, documented the first time the creek stopped running in 1940 (Figure 15: A view of Clover Creek, looking wes).

On the Territorial Township maps recorded in 1877, it appears that what is now Clover Creek was a variety of intermittent streams and wetlands and the stream was non-continuous until reaching the springs at the headwaters of (now) Ponce de Leon Creek. However, an older 1853 Puget Sound Agricultural Claim Map and an 1895 U.S. Geological Survey Map show a continuous perennial stream (Seabrook, cited in Tobiason 2003). The presence of anadromous fish runs in the 1920s and 1930s would support the assumption of a perennial flow. Pierce County came to this conclusion in their 1997 report where they stated, "The Clover Creek basin had perennial flows until the 1930s, and now has intermittent flows" (PCPWU 1997).

Flow problems in the Clover Creek subbasin continue to be of concern. Seven day low flows as well as summer flows in Flett and Leach Creeks, the major tributaries of Chambers Creek, have decreased severely in recent years (Ecology, March 1995, cited in PCPWU 1997). Lack of instream flow in Leach Creek has been cited as the main reason there are no more early run Coho or chum runs in that stream (Brad Caldwell, Pers. comm., Jan. 22, 1996). The Department of Ecology estimates that Leach Creek at 40th Street needs a minimum base flow of 1.5 cfs. However, others contend that 0.7 to 1 cfs is sufficient and there will be enough water to support both resident and anadromous fish (Paul Bucich, Pers. comm., Jan. 18, 1996) (Cited in PCPWU 1997).

Development continues to have an impact on the amount of water remaining in the system. The natural cycle of water returning to the creek has been disrupted as land or housing projects are developed. Small springs, which previously flowed into the stream or through wetlands and then into the creek, are diverted into storm water drains and into the sewer system (Tobiason, Pers. Comm., 2003). The impacts of the cumulative effects of this practice have not been studied, but have probably influenced the stream flow over the years.

Construction of a bridge on 136th Street South resulted in a dry stream bed, documented in photographs taken in July and October, 2002 (Clothier, et al 2003). No water flowed at the new 136th Street South bridge from late spring of 2002 on. The stream bed where the new construction took place was not adequately sealed, and all water was absorbed into the ground under the bridge. Water flowed past the bridge after a Pierce County Water Program tried an experimental sealed low-flow channel through 70 feet of bridge area. Water then absorbed into the ground several hundred feet below the bridge, just short of making it to the asphalt channel (Clothier, et al 2003).

<u>Water Quality</u>

Water quality in the Clover Creek basin is a serious concern. Urbanization, commercial and industrial development, and the continuing presence of small- and medium-sized livestock agricultural activity have all contributed to water quality problems that may affect salmon health in the basin.

Historical data from the creek has focused on total coliform concentrations because of concerns about groundwater quality contamination from on-site sewage systems. More recent studies have been more comprehensive.

In 1981, The Washington State Department of Social and Health Services (DSHS) completed a groundwater survey of Chambers-Clover Creek drainage basin. The survey found coliform bacteria at 29.5% of the groundwater sites sampled (117). In addition, 21.4% of the sample sites exceeded state standards for coliform bacteria at one time or another. The southeast portion of the basin exhibited the highest levels of contamination; coliform was present in 47% of the samples and 38.9% exceeded state limits for coliform levels (Littler 1981, cited in PCPWU 1997).

DSHS also found nitrate and nitrogen levels to be a concern because they were rising from historic levels. In the 1960's, average aquifer levels were approximately .5 mg/l, while the 1981 survey found an average of 1.6 mg/l. Eight survey sites were found to have levels of greater than 5 mg/l. The state standard for nitrate-nitrogen in drinking water is 10 mg/l. As a result of these findings, DSHS recommended that a comprehensive geohydrologic study be performed in the basin, ongoing monitoring be initiated, and that Pierce County develop a groundwater management plan for the area (Littler 1981, cited in PCPWU 1997).

Three organic chemicals were detected at one sampling site within the watershed just south of the point where Clover Creek passes beneath Interstate 5 near American Lake Gardens. The organic compounds found included: 1,2 dichloroethylene, tetrachloroethylene, and trichloroethylene (Littler 1981 cited in PCPWU 1997). Tetrachloroethylene, also known as perchloroethylene (PCE), is a widely used solvent and degreaser, commonly used by drycleaners among others. It affects the central nervous system, is highly volatile, and is not water soluble. Trichloroethylene (TCE) is a common degreasing agent which is widely used by both industries and households. TCE is highly volatile and poorly soluble in water. TCE attacks the nervous system and has been found to cause liver damage in lab animals. TCE has been shown to be toxic to fish. 1,2-dichloroethylene is a breakdown product of PCE and TCE. The location of these contaminants near McChord AFB may be showing effects related to past military activities such as large scale cleaning operations (Littler 1981 cited in PCPWU 1997), however, it may also be possible that poor practices by a local dry cleaner may have contributed to the contamination. Identification of these substances prompted efforts to provide an alternative supply of drinking water to residents within the American Lake Gardens Tract who were being served by private wells. A substantial cleanup effort was also instigated. Two scrubbing towers were installed near 1-5 to remove these compounds and groundwater treatment plants are now in operation on McChord AFB and Ft. Lewis (Grenko, Pers. comm., 2003).

A comprehensive geohydrologic study was performed on the Chambers-Clover Creek basin in 1985 by Brown and Caldwell under the direction of the Tacoma-Pierce County Health Department. The study found that nitrate concentrations in the shallow groundwater had increased by about 40% throughout the basin over the last 20 years. Chloride levels in the shallow groundwater increased 400-500% while deep aquifer chloride levels increased by 50% in the last 20 years. Nitrate and Chloride levels were sampled because they are considered to be excellent indicators of contamination from sewage. General water quality degradation, as indicated by increased nitrate and chloride levels, seems to be resulting from high density residential areas using on-site sewage treatment and from storm water drywells. The shallow aquifer is showing the highest level of contamination at this time, while the deep aquifer exhibits limited contamination (Brown and Caldwell 1985, cited in PCPWU 1997).

The USGS (1996) found that pollutant loads in the Clover Creek basin tended to be lower in areas with highly permeable soils, such as the lower portion of the basin. The USGS also reported that several lakes (e.g., Spanaway, Tule) in the Clover Creek basin appeared to improve downstream water quality by serving as pollutant "sinks." In contrast, Steilacoom Lake appears to have contributed to elevated copper concentrations in Chambers Creek. Copper sulfate was used to control algae growth in the lake for many years (KCM 1996, cited in Clothier, et al 2003).

Water quality in the Clover Creek/Steilacoom Lake subwatershed has become a topic of concern for many local residents. Steilacoom Lake is being overrun by invasive plant growth and salmon died for unknown reasons in Clover Creek in December 1993. These events have generated a high level of interest in determining what is in these waters that might be causing such serious problems. As a result, a great deal of data is being generated to determine the source of pollutants. Extensive water quality sampling has occurred on Clover Creek by the Department of Interior United States Geological Survey. Groundwater was thoroughly examined by Brown and Caldwell under the direction of the Tacoma-Pierce County Health Department. The Health Department has taken the lead on a detailed study of Steilacoom Lake, which is currently ongoing. The data from other areas provide a clear picture of water quality issues in the Clover Creek/Steilacoom Lake subwatershed. Problem areas, pollutants, and biological impacts have been identified within the description of each water body (PCPWU 1997).

Water quality problems in Clover Creek gained the attention of the media on December 2, 1993 when about 40 adult Coho salmon died after attempting to swim up Clover Creek following the first heavy rain of the season. Reports were made of oddly colored storm water discharges entering the creek upstream of the fish kill. Although samples were taken, no conclusive evidence was found to determine the cause of these deaths (Shields 1993, cited in PCPWU 1997). Nevertheless, the event generated a great deal of concern about pollutants in the creek. It was suspected that the fish kill may have been tied in with a first flush event, as described in the Water Quality section of the Chambers Creek discussion. (For detailed report, see newspaper article, Appendix D.)

Discolored storm water discharge into Clover Creek has been observed from two separate storm drains by Marc Wicke, biologist (Pers. comm. 2003). Native vegetation growth appears to be inhibited near the outlet of one twelve-inch storm water pipe near the intersection of Gravelly Lake Drive and Nyanza Road SW, where cloudy discharge often flows during first flush events. On several occasions discolored water has also been observed flowing from a storm water pipe emptying into Clover Creek under Hwy 7, especially during fall first flush events. In addition, immediately downstream of both these outlets dead adult salmon, full of eggs – killed before having the chance to spawn – were found in the stream.

More study of the presence of contaminants in storm water runoff and their effects upon Clover Creek salmonids is needed.

The major water bodies in this area include Clover Creek, Steilacoom Lake, Ponce de Leon Creek, Morey Creek, and Spanaway Creek. Spanaway, Morey, and Ponce de Leon Creeks are discussed in their own sections. Following is a discussion of the water quality in the Upper Clover creek, North Fork of Clover Creek, and Lower Clover Creek sections of the Clover Creek subbasin, including Steilacoom Lake.

Upper Clover Creek

The first water quality testing in Clover Creek focused on total coliforms. Total coliform counts taken from Clover Creek at Waller Road between 1962 and 1973 ranged from 36 to 1400 organisms/100ml (ULID 73-1 1975, cited in PCPWU 1997). In 1973, the state standards for maximum total coliform levels for Class A waters was 240 organisms/100ml.

The United States Geological Survey (USGS) performed an intensive water quality sampling effort on Clover Creek from 1991 to 1992. (Because USGS has not yet issued an assessment of this data, the data USGS collected will be compared to state water quality standards and to other measures taken within the system.) Dissolved oxygen levels dropped below the WAC 173-201A minimums of 8 mg/L at two sites on the creek; just downstream of Waller Road and downstream of McChord Air Force Base. The lowest dissolved oxygen reading of 5.6 mg/L was taken at Waller Road. Fecal coliform counts exceeded WAC 173-201A maximum levels at all sampled sites on the creek with the exception of one main stem location just upstream of Clover Creek's confluence with the North Fork. The highest fecal coliform counts were taken from tributaries draining the area north of Brookdale Road. Two sites on the North Fork also had unusually high concentrations of dissolved zinc, reaching 70 ug/L. Moderately high levels of copper were found downstream of McChord Air Force Base. In addition, lead concentrations were moderately high at two sites on the North Fork, at Spanaway Loop Road, and downstream of McChord (USGS 1994, cited in PCPWU 1997).

Suspended sediment levels were also highest in those creeks draining the area north of Brookdale Road. Concentration of over 100mg/L were not uncommon among those tributaries. The highest concentration (1020 mg/L) was collected from the North Fork at Brookdale Road (USGS 1994, cited in PCPWU 1997).

The USGS (1996) reported that concentrations of most pollutants (metals, bacteria, nutrients) were low in the upper portion of the creek compared to those in other portions of the Clover Creek basin. The relatively low concentrations were attributed to the highly permeable surficial soils, which effectively limit direct discharge to lakes or streams. In this portion of WRIA 12, most rainfall infiltrates either directly (in unpaved areas) or via dry wells (in developed areas). Pollutant transport through subsurface flow is generally much less efficient than transport though direct surface pathways (e.g., storm sewers, drainage ditches). Contaminants in this subsurface flow are removed though a variety of natural processes, such as physical filtering, adsorption, biological decomposition, and geochemical precipitation. Subsurface flow rates are generally slow compared to surface rates, providing more time for contaminant removal to occur. However, some common pollutants, such as nitrate nitrogen, are quite mobile in ground water. The USGS (1996) suggested that fertilizer use and on-site wastewater disposal systems could contribute elevated nitrate levels in surface water bodies in this portion of WRIA 12 (Clothier, et al 2003).

As mentioned earlier, water quality problems in Clover Creek gained the attention of the media on December 2, 1993 when about 40 adult Coho salmon died after attempting to swim up Clover Creek following the first heavy rain of the season. Reports were made of oddly colored storm water discharges entering the creek upstream of the fish kill. Although samples were taken, no conclusive evidence was found to determine the cause of these deaths (Shields 1993, cited in PCPWU 1997).

Water quality problems in storm water runoff peak in the urban and industrial areas of the watershed in early fall. At the beginning of the rainy season, generally in September, a first flush rain event occurs after the extended summer period of little or no rainfall. In these instances, the rain washes pollutants off of surfaces where they have been collecting during the dry season. Storm water runoff typically contains higher concentrations of pollutants during first flush events (PCPWU 1997).

North Fork Clover Creek

The USGS (1996) found that ammonia, phosphorus, fecal coliform, and suspended solids were higher in the North Fork than in other portions of the Clover Creek basin. The highest nutrient concentrations observed during the USGS study were in a tributary draining a residential development in this area. Dissolved zinc concentrations were relatively high (up to 0.070 mg/L) at two locations. The highest suspended solids concentration (1,020 mg/L) was collected near the downstream end of this reach of Clover Creek. The relatively high pollutant concentrations may reflect the low-permeability till soils and urban land use that dominate this area. The low-permeability soils limit infiltration, so runoff from developed areas quickly reaches streams via surface runoff, with relatively little opportunity for pollutant removal (PCPWU 1997).

Lower Clover Creek/Steilacoom Lake

Students from the Environmental Studies program at Pacific Lutheran University sampled the creek in the summers of 1993 and 1994. DO levels in 1993 were below WAC 173-201A minimums (8 mg/L) at 133rd and Pacific and downstream of McChord Air Force Base. DO levels fell as low as 4.6 mg/L at the McChord site in 1993. In 1994, concentrations of DO did not comply with WAC 173-201A standards at only one site downstream of McChord. Fecal coliform samples from 1993 were fairly low with only one sample above the WAC 173-201A maximum. A reading of 1060 organisms/100 ml was taken from the creek at Pacific Avenue and 133rd. In 1994, all numbers were very high with averages for five sites ranging from 440 to 2653 organisms/100 ml. Out of 13 samples taken from the creek in 1994, only one met WAC standards. Temperature readings complied with state standards on all sites in both years (Pagel, Lusk, Adair, Nelson, Washington 1994, and Barker, King, Knapp, Vinciguerre, 1993, cited in PCPWU 1997).

The USGS reported that water quality in this portion of the drainage was generally similar to the North Fork but worse than the Upper Clover and Spanaway sub-watersheds. Pollutant concentrations were considerably higher during storm events, reflecting elevated loads from the North Fork as well as surface runoff from developed areas in the Lower Clover Creek sub-watershed (USGS 1996).

Pacific Lutheran University students sampled lower Clover Creek in the summers of 1993 and 1994. DO levels did not meet the state standards downstream of McChord AFB on several occasions. The lowest DO level was 4.6 mg/L. Fecal coliform frequently exceeded the state standard. Water temperatures generally complied with state standards (Pierce County, 1997).

McChord AFB sampled Clover Creek where it enters and leaves the base on 11 occasions during 1999-2001 (PCPWU 1997). Samples were analyzed for oil and grease, phenols, lead, mercury, silver, phosphorus, pH, and temperature. Most samples had concentrations of metals and oil and grease below detection limits. Phosphorus in Clover Creek ranged from <0.010 mg/L to 0.060 mg/L. The maximum temperature in Clover Creek was 16.9 degrees Celsius at the upper Clover Creek station (i.e., where the Creek enters the base). One upper Clover Creek sample was slightly below the state minimum for pH. In general, the samples showed little change in Clover Creek water quality upstream and downstream of McChord AFB. Charts showing results of pH and phosphorus testing on McChord AFB from 2000-2003 are included in Appendix F.

Clover Creek ultimately discharges to Steilacoom Lake, which also receives considerable inflow from Ponce de Leon Creek. Steilacoom Lake has had severe problems with excessive growth of algae and waterweeds. For many years, the Lake was treated with copper sulfate to control the algae growth and other aquatic herbicides to control aquatic plant growth. As a result, the Lake sediments contain relatively high concentrations of copper. A 1996 lake restoration study determined that the excessive algae growth was triggered by elevated phosphorus concentrations. Phosphorus concentrations in Clover and Ponce de Leon Creeks often exceeded the target in-lake concentration of 0.02 mg/L. The average phosphorus concentrations in Ponce de Leon Creek were more than double the target level (PCPWU 1997).

A more recent study (Whitman, et al 2002), published by students of Jill Whitman, PhD, Professor of Geosciences at PLU, found that the areas of greatest concern in Clover Creek are currently dissolved oxygen, fecal coliform, and nitrates. Turbidity has been a problem, but is improving. The results of the study include:

Dissolved Oxygen: The Washington Administrative Code (WAC) sets state standards for the dissolved oxygen content in bodies of water, defining Clover Creek as a Class A stream whose dissolved oxygen level should be above 8.0 mg/L. Clover Creek's DO levels are higher than the state minimum (10-12 mg/L).

Temperature: In order to meet state water quality standards for a Class A stream, the temperature cannot exceed 18 degrees C. For the past 3 years the water temperatures were between 8-10° C, an improvement from previous years.

Fecal Coliform: According to data gathered in 2002, fecal coliform levels were well above the state Class A stream maximum levels of 100 colonies/100 ml. However, data from past years indicates that fecal coliform bacteria have significantly improved since 1996. Past data also shows that fecal coliform tests performed in summer and early fall months tend to be higher. Since tests in 2000-2002 were performed during the spring months, it may be necessary to test year round to determine seasonal fluctuations, in order to determine when fecal coliform typically enters the Clover Creek system.

pH: Water bodies with a pH below 5.0 can cause serious problems and very acidic waters contain heavy metals such as aluminum and copper which can accumulate on and clog fish gills. Most of Clover Creek has a pH of 7 to 7.5.

Nitrate: Due to fertilizers and animal feces, nitrate levels have historically been higher in agricultural areas, such as the Waller Road site. Common lawn fertilizers are often applied at much higher concentrations than grasses require, resulting in excess nutrients washed off into storm drains or the creek itself. Recently though, human sewage has become a larger problem due to unchecked, overflowing septic systems. Clover Creek typically runs about 1-2 mg/L.

Turbidity: The activities that impact the turbidity of a stream are numerous, but it is a very important indicator of the overall health of a stream. Currently, the State of Washington (WAC 173-201A) has set the standard of 5.0 NTU in order for a stream to be given a class AA—extra ordinary classification. All of the five sites met the state standard in 2002, the first time since testing began in 1995.

<u>Lakes</u>

Steilacoom Lake has been included in the preceding discussion as part of the stream system.

<u>Action Recommendations</u>

The following salmonid habitat restoration actions are recommended for the Clover Creek watershed:

Fish Access:

- ◊ Conduct comprehensive fish passage barrier and priority index survey.
- ◊ Remove or replace identified high priority salmonid-blocking culverts, dams, weirs or other blockages with fish-friendly alternatives.

Floodplain Modifications:

- ◊ Work with McChord AFB, local industry, and residents in the Clover Creek and North Fork watersheds to improve floodplain and riparian conditions.
- ◊ Investigate the feasibility of returning the stream to one channel in the area between Golden Given Avenue and 138th Street.

Channel/Substrate:

- ◊ Restore stream to more natural system (sinuosity, habitat complexity, sediment delivery, etc., where possible throughout the stream.
- ◊ Increase channel complexity by addition of instream large woody debris (LWD) in appropriate areas.

◊ Explore methods of sealing the streambed and adjacent ponds in areas where human intervention has broken the natural seal, allowing water loss into the permeable gravels below.
◊ Reduce human-caused sediment delivery to the stream by enforcing appropriate riparian buffers.
◊ Reduce the invasion of reed canary grass.

Riparian:
◊ Maintain and protect existing functional riparian vegetation.
◊ Restore degraded riparian conditions through education and regulation. Use historic information and on-site surveys to restore with the appropriate native plant species, and consider the stream size for a functional riparian buffer.
◊ Eliminate non-native plants from riparian zones, and revegetate with native species.
◊ Reduce riparian wood removal, including removal by private citizens, through education and regulatory actions.
◊ Reduce livestock access to riparian buffers through education and regulatory action.

Water Quantity:
◊ Protect and maintain areas that are important for aquifer recharge.
◊ Seek opportunities to reduce water withdrawals from the drainage.
◊ Explore methods of sealing the streambed and adjacent ponds in areas where human intervention has broken the natural seal, allowing loss of flow into the permeable gravels below.
◊ Conduct public education aimed at informing streamside owners about basic principles of creek stewardship to prevent further breaks in the stream seal due to human intervention.
◊ Follow the recommendations that develop from the Watershed Planning (2514) process.

Water Quality:
◊ Reduce industrial and urban pollution inputs, including storm water run-off, into the drainage.
◊ Conduct study of the impact of the first flush phenomenon in association with storm water runoff in high density, urban areas, on the quality of water in the drainage.
◊ Improve water quality throughout the Clover Creek drainage by addressing the riparian, instream flow, and wetland loss conditions. These are further described in their respective sections.
◊ Address failing septic systems throughout the drainage.
◊ Implement agriculture's Best Management Practices to reduce nutrient runoff and livestock waste delivered to streams in the upper part of the creek drainage.

Peach Creek (1225381471972)

General

Peach Creek is a small stream draining into Chambers Creek just west of Leach Creek. The creek is seasonal and dries up in the summer (PCPWU 1997).

Fish Access

Unknown

Floodplain Modifications

Charles Wright Academy is located adjacent to the creek on its west bank (PCPWU 1997).

Channel and Substrate Conditions

The creek is experiencing some severe scouring problems from high velocity flood waters (PCPWU 1997).

Riparian Conditions

Peach Creek is enclosed within a steep ravine and much of the riparian vegetation has been preserved as a result. Tree coverage and habitat conditions within the ravine of the creek are of excellent quality (PCPWU 1997).

Action Recommendations

The following salmonid habitat restoration actions are recommended for the Peach Creek watershed:

Fish Access:

- ◊ Before a survey to identify barriers on this stream is conducted, the stream should be evaluated for its potential as salmonid habitat.

Channel/Substrate:

- ◊ Investigate the scouring problem and determine if it needs to be dealt with in order to prevent excess sediment transport downstream into Chambers Creek.

Leach Creek 12.0008

General

Leach Creek is a right bank tributary that originates near the community of Fircrest and flows south 2.3 miles where it joins Chambers Creek at RM 2.4 (Williams, et al 1975, cited in PCPWU 1997).

Fish Access

The Bridgeport Way culvert on Leach Creek has been identified as a partial barrier by Washington Department of Fish and Wildlife (WDFW 2003) and has been funded for replacement by the Salmon Recovery Funding Board (SRFB) for 2002 (David Swindale, Personal comm., 2002, cited in Clothier, et al 2003).

No other data is available on fish passage barriers on Leach Creek.

Floodplain Modifications

Upland habitat is fragmented and urbanized, with drier plant communities occurring on the slopes. The development is generally low density residential, with more habitat toward the east and south. Wetlands in the Leach Creek drainage include the large north Leach Creek wetland at the headwaters of the creek, plus numerous scattered wetlands associated with the creek. Large areas of hydric soils occur on the east side of the creek. Since 1961, the North Creek Wetland has been used for storm water detention and retention by the City of Tacoma (Jones and Stokes Associates 1991, cited in PCPWU 1997).

Channel and Substrate Conditions

Although a low proportion of land lying within the riparian corridor of Leach Creek is impervious surface (0 to 20%), the area has a storm water runoff problem. Areas in the upper reaches have a high proportion of impervious surface. Good spawning habitat remains from Chambers Creek all the way to the Bridgeport Way Golf Course, but above that there has been downcutting action of the creek leading to increased sediment loading. This has been described as severe degradation in recent years with severe erosion problems occurring during storm events (Robels 1994, cited in PCPWU 1997). Homeowners have disturbed the streamside by eliminating vegetation of the low canopy and modifying the streambank. This results in channelizing or a conversion of pool/riffle structures to long straight stretches.

The upper reaches of the creek have some good pockets of spawning grounds, but homeowners have disturbed the streamside by eliminating vegetation and channelizing some sections. The creek is slow moving in these upper reaches with an undeveloped riparian corridor providing good salmon rearing habitat and wildlife movement (Jones & Stokes 1991, cited in PCPWU 1997).

Riparian Condition

According to the Chambers-Clover Creek Management Committee Watershed Characterization (PCPWU 1997), Leach Creek has no continuous riparian cover, and vegetation along the stream exists only in fragments. Development along the creek is primarily residential, and many of the owners have removed low canopy vegetation along the creek.

AES found this to be somewhat inconsistent with the results (Table 5: Data Summary of Leach Creek Riparian Corridor). Although the habitat was somewhat fragmented due to urbanization, Leach Creek was found to have more riparian corridor along its length than previously documented by Pierce County. A good riparian zone average width was also measured. Percent shade cover was determined to be 76% to 100%. This percentage parallels that of creek length with riparian cover, leading AES to conclude that a high percentage of the existing riparian cover offers shade for the creek (Clothier, et al 2003).

Table 5: Data Summary of Leach Creek Riparian Corridor

	North/West Bank	**South/East Bank**
Approximate Creek Length	11,688 feet	11,688 feet
Percentage of Creek Length with Riparian Cover	9702 feet 83.0%	10,777 feet 92.2%
Average Width of Riparian Corridor	252 feet	227 feet
Percent Shade Cover	**76%-100%**	

(Clothier, et al 2003)

Some invasive species encroachment has been observed along the creek, including a stand of Japanese knotweed along the bank at approximately RM 0.6 (Marcantonio, Pers. comm., 2003).

Water Quantity

The gauges along Flett Creek and Leach Creek show flow patterns typical for streams in western Washington. In general, flow rates are at their lowest level from May through September and reach their highest level in the wet winter months (Clothier, et al 2003).

Activities related to the cleanup of the Tacoma Landfill near Fircrest have had an impact on flow within Leach Creek. The current headwaters are within two miles of the landfill. The landfill was in operation for about 30 years before landfills were required to place liners beneath the waste they collected. As a result, contamination from the landfill infiltrated the groundwater. The City of Tacoma has constructed a number of extraction wells around the perimeter of the landfill and near Leach Creek to treat the contaminated water. The extraction wells remove volatile organic compounds and other contaminants. The resulting flow is directed to the Tacoma Sewage Treatment Plant. It is unclear how much the redirection of this groundwater flow has impacted the original flow levels of the creek but the City of Tacoma agreed to augment creek water levels. Tacoma constructed a well that pulls uncontaminated water from the sea-level aquifer and directs a small amount of it into the Leach Creek Holding Basin. At 40th Avenue the creek currently averages about 2 cubic feet per second with augmented flows (Paul Bucich 1994, cited in PCPWU 1997).

Instances of high flow storm events have taken place with greater frequency in recent years, with significant streambank erosion and private property inundation taking place in the cities of Fircrest and University Place. Evidence of stream down-cutting has been observed at various points in the basin (Marcantonio, Pers. comm., 2003). Private property owners have reported higher flows associated with flood events that they believe are associated with increased development around the Leach Creek Holding Basin, in the north portion of the City of Fircrest. The Holding Basin receives surface water from residential and commercial development in the City of Tacoma, as well as a small amount of groundwater pumped from the west margin of a City of Tacoma landfill south of Cheney Stadium (discussed more fully below). In the past the City of Tacoma has been targeted by private property owner lawsuits related to this flooding. A committee has been formed of interested jurisdictions to look into the problem. The City of Tacoma Public Works Department has begun a study of flow rates and actions that may be taken to alleviate high flow associated with storm events in the basin.

Water Quality

The area draining into Leach Creek is characterized by low permeable soils which results in high storm water runoff. The creek is 2.2 miles long and drains the University Place community into Chambers Creek (Brown & Caldwell 1985, cited in PCPWU 1997). The headwaters of Leach Creek once originated in the vicinity of North 30th Street and Pearl Street in the City of Tacoma. A series of potholes (small basin shaped depressions) in the region once held a certain amount of water and contributed any excess storm water into the creek. A large wetland in the vicinity of the town of Fircrest probably contributed the greatest amount of flow. The headwaters area is now heavily urbanized and covered by extensive amounts of impervious surface. Runoff is currently piped into a 42-acre holding basin at South 37th Street before it is directed into Leach Creek. The creek is now supplied by water from this holding basin, flow from a large wetland north of 53rd Avenue, localized springs, and by some smaller, intermittent creeks (PCPWU 1997).

Sampling has been performed by the City of Tacoma as part of its National Pollutant Discharge Elimination System (NPDES) permit application and reported generally good water quality. Creek sediment samples collected by the city in April 1989 met the proposed state sediment quality criteria for metals, chlorinated hydrocarbons, phthalates, phenol, volatile organics, and pesticides. They found the headwaters of Leach Creek, at the outlet of the detention pond at 40th Street, to have a slightly elevated total chlorine level of 0.3 mg/L. The water was clear with no surface scum or oil sheen. The pH level was about 7.35 and most other readings were below detection limits of levels of concern. Leach Creek sediment samples taken in April of 1989 were compared to proposed sediment standards by City of Tacoma staff. Metal, chlorinated hydrocarbon phthalate, phenol, volatile organic, and pesticide levels were well within compliance levels. However, levels for organics, such as PAHs, often exceeded the proposed standards. PAHs come from engine combustion and burning. They are resistant to environmental degradation and are considered carcinogenic (City of Tacoma 1993, cited in PCPWU 1997).

Action Recommendations

The following habitat restoration actions are recommended for Leach Creek:

Fish Access:

- ◊ Conduct comprehensive fish passage barrier and priority index survey.
- ◊ Remove or replace identified high priority salmonid-blocking culverts, dams, weirs or other blockages with fish-friendly alternatives.

Floodplain Modifications:

- ◊ Work with local industry, and residents in the Leach Creek watershed to improve floodplain and riparian conditions.

Channel/Substrate:

- ◊ Restore stream to more natural system (sinuosity, habitat complexity, sediment delivery, etc., where possible throughout the stream.
- ◊ Increase channel complexity by addition of instream large woody debris (LWD) in appropriate areas.

Riparian:

- ◊ Maintain and protect existing functional riparian vegetation.
- ◊ Restore degraded riparian conditions through education and regulation. Use historic information and on-site surveys to restore with the appropriate native plant species, and consider the stream size for a functional riparian buffer.
- ◊ Eliminate non-native plants from riparian zones, and revegetate with native species.
- ◊ Reduce riparian wood removal, including removal by private citizens, through education and regulatory actions.

Water Quantity:

- ◊ Follow the recommendations that develop from the Watershed Planning (2514) process.

Water Quality:

- ◊ Improve water quality throughout the Leach Creek drainage by addressing the riparian, instream flow, and wetland loss conditions. These are further described in their respective sections.
- ◊ Reduce industrial and urban pollution inputs, including storm water run-off, into the drainage.

Flett Creek 12.0009

General

Flett Creek is a right bank tributary that originates near the community of Manitou in Tacoma. It flows south then west 3.1 miles to its confluence with Chambers Creek at RM 2.55 (Williams, et al 1975) (PCPWU 1997).

Fish Access

In September 2000, a barrier to fish passage located under the 75th Street West bridge was removed and the stream was returned to natural conditions.

The first known barrier to fish passage in Flett Creek is located at the downstream end of the detention ponds at ~RM 2.0, located on the west edge of Mountain View Memorial Park.

A comprehensive survey of fish passage barriers has not been completed for Flett Creek.

Figure 16: A barrier located immediately under 75th Street West
(Photo by Pierce Conservation District)

Figure 17: The barrier was removed and native plants placed along the banks
(Photo by Pierce Conservation District)

Floodplain Modifications

Though Snake Lake is located at the head of the Flett Creek basin, it is not directly connected to the Flett Creek channel. Overflow from the lake reaches the stream through a series of drain pipes and wetlands during periods of high rainfall (Desiree Pooley, City of Tacoma, Pers. comm., 2003).

The valley between South Tacoma and the Manitou community also drains to the creek. The area of the valley within the City of Tacoma has been altered by commercial and industrial uses, including groundwater contamination. Approximately half of the drainage in the upper reaches of Flett Creek is over 40% impervious surface (PCPWU 1997).

Upland habitat in the upper Flett Creek basin has been altered extensively for residential and commercial use. Historic spawning areas were lost where the creek curves north into the City of Tacoma (Chappell 1979, cited in PCPWU 1997) when the detention ponds were put in place.

Channel and Substrate Conditions

Two miles of the creek were channelized in 1986 to improve drainage. In 1980, four retention ponds were installed in the creek (Brown & Caldwell 1985) above ~RM 2.0.

Nearly three decades ago, it was reported in the Stream Catalogue that Flett Creek contained good gravel and pool-riffle balance in the lower half of the stream (Williams 1975). A more recent survey of substrate conditions has not been completed.

Riparian Condition

According to Pierce County (1997), Flett Creek has no continuous riparian cover, and vegetation along the stream exists only in fragments. The riparian zone has been modified for residential and commercial use, leading to the degradation of the riparian functions (PCPWU 1997). Shrub cover is nonexistent except in a wetland in the middle reaches of the creek, but tree cover exists on some reaches of the creek.

Table 6: Data Summary of Flett Creek Riparian Corridor

	North/East Bank	**South/West Bank**
Approximate Creek Length	11,316 feet	11,316 feet
Percentage of Creek Length with Riparian Cover	11,129 feet 98.3%	10,591 feet 93.6%
Average Width of Riparian Corridor	333 feet	567 feet
Percent Shade Cover	**26%-50%**	

(Clothier, et al 2003)

The percentage of creek length with riparian cover and the average riparian width are both relatively high, because the wetland exists along so much of the length of the creek. The rest of the creek length, however, has little if any riparian corridor. Although the wetland is primarily scrub/shrub, it performs a necessary riparian function for the creek. This habitat is used by waterfowl and other wildlife species and offers a good riparian zone. Percent shade cover was determined to be 26% to 50% (Table 6: Data Summary of Flett Creek Riparian Corridor). This percentage does not parallel that of creek length with riparian cover, because the wetland providing riparian habitat is primarily scrub/shrub in nature and provides little shade for the creek (Clothier, et al 2003).

At the head of Flett Creek basin, the Snake Lake Nature Center contains areas of natural forest, some portions dominated by second-growth hardwoods as well as the main wetland (PCPWU 1997). However, this area is not directly connected to the Flett Creek channel (Cooley, Pers. comm., 2003).

Water Quantity

A large portion of the creek's flow is from localized springs. Well pumping for drinking water has reduced the flow of the creek by 2-4 cfs. Peat deposits line the bed of Flett Creek and provide a barrier between the creek and the highly permeable soils beneath. When the retention ponds were installed in the creek in 1980, they were created by removing the peat layer and exposing the stream flow to the underlying permeable gravels, causing rapid infiltration of available water and subsequent reduction of flow in the creek (Brown & Caldwell 1985).

Water Quality

Little water quality information is available for Flett Creek. Two storm event samples collected in 1993 by Pierce County Surface Water Management met state water quality standards, although they did contain detectable levels of lead, copper, and zinc.

All samples showed levels well within compliance with state water quality standards. However, the measures for total dissolved solids were unusually high at 179 mg/L and 137 mg/L. Lead and zinc levels, although detected, were fairly low. Copper levels were moderate to low at 0.02 mg/L and 0.009 mg/L (Pierce County 1993, cited in PCPWU 1997).

Action Recommendations

The following salmonid habitat restoration actions are recommended for Flett Creek:

Fish Access:
- ◊ Conduct comprehensive fish passage barrier and priority index survey.

Floodplain Modifications:
- ◊ Work with local industry, and residents along Flett Creek to improve floodplain and riparian conditions.

Channel/Substrate:
- ◊ Restore stream to more natural system (sinuosity, habitat complexity, sediment delivery, etc., where possible throughout the stream.
- ◊ Increase channel complexity by addition of instream large woody debris (LWD) in appropriate areas.
- ◊ Reduce human-caused sediment delivery to the stream by enforcing appropriate riparian buffers.
- ◊ Reduce the invasion of reed canary grass.

Riparian:
- ◊ Maintain and protect existing functional riparian vegetation.

◊ Restore degraded riparian conditions through education and regulation. Use historic information and on-site surveys to restore with the appropriate native plant species, and consider the stream size for a functional riparian buffer.
◊ Eliminate non-native plants from riparian zones, and revegetate with native species.
◊ Reduce riparian wood removal, including removal by private citizens, through education and regulatory actions.

Water Quantity:
◊ Protect and maintain areas that are important for aquifer recharge.
◊ Seek opportunities to reduce water withdrawals from the drainage.
◊ Investigate methods to repair the seal broken when the retention ponds were built in 1980, in order to reduce water loss through infiltration.
◊ Follow the recommendations that develop from the Watershed Planning (2514) process.

Water Quality:
◊ Increase water quality monitoring in the drainage.
◊ Improve water quality throughout the Leach Creek drainage by addressing the riparian, instream flow, and wetland loss conditions. These are further described in their respective sections.
◊ Reduce industrial and urban pollution inputs, including storm water run-off, into the drainage.

Ponce de Leon Creek 12.0010

General

Ponce de Leon Creek is a right bank tributary originating at the Lakewood Mall and entering the southern half of Steilacoom Lake (Williams, et al 1975).

Fish Access

A dam blocks passage about 700 feet upstream from the mouth of Ponce de Leon Creek (PCPWU 1997).

Floodplain Modifications

Ponce de Leon Creek was the historic, most downstream portion of the Clover Creek channel, immediately upstream from Steilacoom Lake. Much of an alternate western segment of Clover Creek was widened and deepened during the 1930s and early 1940s to help alleviate winter flooding problems. The natural channel extending from the McChord western boundary to (present day) Ponce De Leon Creek was abandoned when the present day channel was widened and deepened. Approximately 4.0 miles of the creek were dredged during this project (Clothier, et al 2003). Lakewood Mall was subsequently built over a portion of the historic channel area.

Channel and Substrate Conditions

Ponce de Leon Creek, which drains from the Lakewood Mall into Lake Steilacoom, has good instream habitat for Coho spawning (PCPWU 1997).

Riparian Condition

The creek has good riparian habitat for Coho spawning (PCPWU 1997).

Water Quantity

Ponce de Leon Creek daylights at Gravelly Lake Road. Its surface drainage area is small (<0.5 square mile). However, it is fed primarily by groundwater discharge. Based on the volume of discharge, Ponce de Leon Creek's groundwater basin may be quite large (>10 square miles) (Clothier, et al 2003).

Water Quality

Steilacoom Lake receives considerable inflow from Ponce de Leon Creek. A 1996 lake restoration study found that phosphorus concentrations in Ponce de Leon Creek often exceeded the target in-lake concentration of 0.02 mg/L. The average phosphorus concentrations in Ponce de Leon Creek were more than double the target level. The study hypothesized that much of the phosphorus found in Ponce de Leon Creek may be from muck soils located a short distance upgradient of the lake (KCM 1996).

The Department of Ecology recently awarded a grant to the City of Lakewood to identify the sources of phosphorus affecting the lake. The study should be completed in 2003 (Clothier, et al 2003).

Action Recommendations

The following habitat restoration actions are recommended for Ponce de Leon Creek:

Fish Access:

- ◊ Remove or provide fish access around the dam 700 feet upstream from its mouth.

Water Quality

- ◊ Examine the results of the study commissioned by the City of Lakewood, and determine what action should be taken based on that study.

Morey Creek 12.0011

General

Morey Creek is a left bank tributary entering Clover Creek at ~RM 9.15 (Williams, et al 1975). It separates from Spanaway Creek, has a poorly defined channel and has a number of associated wetlands. The creek forms two channels in its central portion, and dense wetland vegetation fills the expanse between them (PCPWU 1997).

Fish Access

The most recent known survey of the Clover Creek area was conducted by Ron Whitney of the Washington Department of Fish and Wildlife (Memorandum from Whitney to Chris Detrick, February 11, 1988, unreferenced). During this survey, a nine-foot high concrete dam was found containing the water of Morey Pond, just 115 feet upstream from the mouth of the creek (Figure 18: The concrete dam on Morey Creek). At the time of the survey, no water flowed above ground below the dam, although some water flow entered the pond at the upstream end. Above Morey Pond, a culvert under one of the [McChord Air Force] base roads presented no fish passage problems.

The TetraTech/KCM (2002) study for Pierce County also made note of a concrete weir at the downstream end of Morey Creek.

Figure 18: The concrete dam on Morey Creek
(Photo by Pierce Conservation District)

Floodplain Modifications

Much of the western segment of Clover Creek was widened and deepened during the 1930s and early 1940s to help alleviate winter flooding problems. Within the borders of McChord AFB, Clover Creek and the western 2,000 feet of Morey Creek were dredged to a depth of about 12 feet. Approximately 4.0 miles of the creek were dredged during this project (Clothier, et al 2003).

Channel and Substrate Conditions

The channel of Morey Creek, with the exception of that portion contained on McChord AFB, has been modified only locally. Over most of its length, Morey Creek flows in a poorly defined channel bordered by dense growths of willows, cattails, and reed canary grass. In the central portion, for a distance of several hundred feet, the creek forms two channels between which a boggy area with dense undergrowth has formed. Thick accumulations of organic rich silt cover much of the Steilacoom gravel which makes up the bed of the creek (Clothier, et al 2003).

Riparian Conditions

Much of the bank of Morey Creek was found to be without riparian cover, as this region of the watershed is heavily developed. Percent shade cover was determined to be 26% to 50% due to urban development (

Table 7: Data Summary of Morey Creek Riparian Corridor). This percentage parallels that of creek length with riparian cover, leading AES to conclude that although not much riparian habitat exists, a high percentage of the existing riparian cover offers shade for the creek (Clothier, et al 2003).

The wetlands associated with the creek have good vegetative cover and provide reasonably high quality wetland habitat (PCPWU 1997).

Table 7: Data Summary of Morey Creek Riparian Corridor

	North Bank	**South Bank**
Approximate Reach Length	5,447 feet	5,447 feet
Percentage of Creek Length with Riparian Cover	1,964 feet 36.1%	2,385 feet 43.8%
Average Width of Riparian Corridor	112 feet	444 feet
Percent Shade Cover	**26%-50%**	

(Clothier, et al 2003)

Water Quantity

The streams in the Clover Creek basin have built up deposits of silt and organic material over thousands of years, offering an effective natural seal which inhibits the loss of water due to percolation into the Steilacoom gravel and Spanaway Loam. However, many human activities have broken this seal, allowing for high losses of water from the streams into the underlying groundwater. Activities such as dredging, rechanneling, and digging ponds break this natural barrier and have been pinpointed as probable locations for high losses of water in the stream. No extensive study of stream flow has occurred on Spanaway/Morey creeks to determine stream flow losses due to the loss of the natural seal, but it is likely that the ponds and any work done which may have damaged the stream bed has led to water losses (Isensee 1991).

During an investigation in 1986, twelve ponds and five pump diversions were identified on Spanaway and Morey Creeks. Since the pumps were used primarily during the summer months for lawn and garden watering, their impact on creek flow during low flow periods may be significant. All of the ponds along Spanaway and Morey Creek are underlain by Steilacoom gravel. None of the ponds are effectively sealed (Sinclair and Carter, 1986).

Water Quality

Table 8: Water Quality Measured in Morey Creek on McChord AFB

Date	DO (mg/L)	Temp (C)	pH	Nitrogen (mg/L)
Jan. 31, 1991	11.9	6	7.1	0.65
Oct. 31, 1990	6.0**	11	7.3	0.68
Jul. 31, 1990	7.2	24	7.5	0.68
Jan. 31, 1990	7.8	8	6.9	2.36
Jun. 30, 1989	9.8	23	7.2	0.20
Mar. 31, 1989	4.8	11	7.3	1.48
Dec. 28, 1988	3.8	5	6.8	1.10
Sep. 30, 1988	7.0	15	7.2	1160.00 (?!?)
Jun. 3, 1988	7.2	11	7.2	0.47
Mar. 31, 1988	4.5	16	7.2	0.78
Dec. 8, 1987	3.9	5	7.1	0.48
Oct. 20, 1987		4	7.3	
Sept. 21, 1987	4.9	20	7.2	0.56
McChord Compliance Standard	9.5	15	6.5 -8.5	0.90

**Numbers in boldface do not meet minimum water quality requirements.
Data supplied by Robert Mcdonald, Natural Resources Specialist, McChord AFB

Samples taken by USGS in Morey Creek had temperatures higher than the maximum allowed in WAC 173-201A (Table 8: Water Quality Measured in Morey Creek on McChord AFB). Dissolved oxygen levels in the creek were too low to meet state standards with four samples falling below 8 mg/L. Tetrachloroethylene was detected at this site at a concentration of 0.3 mg/L which is well below EPA minimum contamination levels but it is the only priority organic pollutant detected within the basin (USGS 1994 cited in PCPWU 1997). Tetrachloroethylene or perchloroethylene (PCE) is a degreasing solvent which depresses the central nervous system, causes liver damage in mammals, and causes cancer in mice. The breakdown products of PCE are also considered dangerous to human health (PCPWU 1997).

Fisheries habitat within the creek may be limited by the low oxygen levels and high temperatures commonly associated with wetland type environments (PCPWU 1997).

<u>Action Recommendations</u>

The following salmonid habitat restoration actions are recommended for Morey Creek:

Fish Access:

- Conduct comprehensive fish passage barrier and priority index survey.
- Remove or replace identified high priority salmonid-blocking culverts, dams, weirs or other blockages with fish-friendly alternatives, including the dam already identified near the mouth of the creek.

Floodplain Modifications:

- Work with McChord AFB and residents along Morey Creek to improve floodplain, wetland, and riparian conditions.

Channel/Substrate:

- Restore stream to more natural system (sinuosity, habitat complexity, sediment delivery, etc., where possible throughout the stream. In some cases, this may involve removal of choking vegetation.
- Reduce the invasion of reed canary grass.

Riparian:

- Maintain and protect existing functional riparian vegetation.
- Restore degraded riparian conditions through education and regulation. Use historic information and on-site surveys to restore with the appropriate native plant species, and consider the stream size for a functional riparian buffer.
- Eliminate non-native plants from riparian zones, and revegetate with native species.
- Reduce riparian wood removal, including removal by private citizens, through education and regulatory actions.

Water Quantity:

- Explore methods of sealing ponds more effectively to prevent loss of water due to infiltration.
- Seek opportunities to reduce water withdrawals from the drainage.
- Study stream flow in Morey Creek to determine the extent of stream flow losses.

◊ Follow the recommendations that develop from the Watershed Planning (2514) process.

Water Quality:

◊ Improve water quality, especially water temperature and DO in Morey Creek by addressing the riparian, instream flow, and wetland loss conditions. These are further described in their respective sections.

◊ Reduce industrial and urban pollution inputs into the drainage.

Spanaway Creek 12.0012

(Coffee Creek 12.0012)

General

Spanaway Creek originates in several springs and marshes, including Spanaway Marsh, on Fort Lewis. Locally it is referred to as Coffee Creek until it enters Spanaway Lake. It continues as the outlet for Spanaway Lake. The stream channel splits, also providing flow for Morey Creek, and eventually enters Clover Creek about 0.25 mi. downstream of Tule Lake at RM 9.85 as a left bank tributary (Williams, et al 1975, cited in PCPWU 1997).

Fish Access

The following barriers to fish passage have been identified on Spanaway Creek:

A dam was constructed in 1894 on Spanaway Creek 800 feet downstream from Spanaway Lake to power two water wheels. The WDFW currently utilizes the dam to keep trout stocked in the lake from moving downstream; unfortunately the dam also blocks upstream migration (Pettit 2000).

The following habitat problem is tied to a specific location on Spanaway Creek (TetraTech/KCM 2002):

- A 6-foot-high concrete weir (spillway) crosses the entire width of Spanaway Creek approximately 2,200 feet downstream of Spanaway Lake. This weir presents a barrier to upstream migration for all fish species during all times of the year. It is owned and maintained by the Washington State Department of Fish and Wildlife.

A comprehensive survey of the creek has not been completed, but the existence of barriers is acknowledged: Spanaway Creek has fish passage barriers, and the existing structures allow little or no access for migrating salmonids upstream (Mobrand Biometrics 2001, cited in Clothier, et al 2003).

Floodplain Modifications

Several man-made ponds have been constructed using Spanaway Creek as a source of water. These ponds were constructed by adjacent homeowners for irrigation, aesthetics, fish rearing, and other purposes. They are maintained by the property owners (Ecology 1986, cited in PCPWU 1997).

Channel and Substrate Conditions

Spanaway and Morey Creeks have not been extensively dredged like the remainder of Clover Creek's western portion. Minor modification of the Spanaway Creek channel occurs locally where water is diverted to fill several man-made ponds prior to joining with Clover Creek one quarter mile below Tule

Lake. The bed of Spanaway Creek alternates from clean gravel and cobbles overlain by thin deposits of organic rich silt. Local swamps have formed where the creek banks are not well maintained. They contain an abundance of cattails, willows, and reed canary grass (Clothier, et al 2003).

Riparian Conditions

Spanaway Creek was found to have a significant riparian zone along its length. This is partially due to the fact that it runs through Tule Lake and its associated wetlands. Percent shade cover was determined to be 76% to 100% along Spanaway Creek (Table 9: Data Summary of Spanaway Creek Riparian Corridor). This percentage parallels that of creek length with riparian cover, leading AES to conclude that a high percentage of the existing riparian cover offers shade for the creek (Clothier, et al 2003).

Table 9: Data Summary of Spanaway Creek Riparian Corridor

	North/East Bank	**South/West Bank**
Approximate Creek Length	11,292 feet	11,292 feet
Percentage of Creek Length with Riparian Cover	9,937 feet 88.0%	9,796 feet 86.8%
Average Width of Riparian Corridor	497 feet	562 feet
Percent Shade Cover	**76%-100%**	

(Clothier, et al 2003)

Water Quantity

The streams in the Clover Creek basin have built up deposits of silt and organic material over thousands of years, offering an effective natural seal which inhibits the loss of water due to percolation into the Steilacoom gravel and Spanaway Loam. However, many human activities have broken this seal, allowing for high losses of water from the streams into the underlying groundwater. Activities such as dredging, rechanneling, and digging ponds break this natural barrier and have been pinpointed as probable locations for high losses of water in the stream. No extensive study of stream flow has occurred on Spanaway/Morey creeks to determine stream flow losses due to the loss of the natural seal, but it is likely that the ponds and any work done which may have damaged the stream bed has led to water losses (Isensee 1991).

A Deptartment of Ecology investigation identified twelve ponds and five pump diversions on Spanaway and Morey Creeks. Since the pumps are used primarily during the summer months for lawn and garden watering, their impact on creek flow during low flow periods may be significant. All of the ponds along Spanaway and Morey Creek are underlain by Steilacoom gravel. None of the ponds are effectively sealed (Sinclair & Carter 1986).

Water Quality

The Pierce Conservation District's Stream Team coordinates water quality testing (Level 2) at one sample site on Spanaway Creek below Spanaway Lake, and at one site above the lake. The creek is a Class A stream; test results for the creek generally fall within Washington State Class A standards for DO, pH, and temperature (See Table 2: Surface Water Quality Standards for Washington Class A Waters). On occasion, DO readings fall below the standards at the site above the lake, which is not unexpected, since it is not far downstream from the originating wetland (Isabel Ragland, Pers. comm., 2003).

In a study of Spanaway Lake, USGS reported moderate levels of nutrients and fecal coliform bacteria and low levels of metals in this portion of WRIA 12. This was attributed to pollutant removal in Spanaway and Tule Lakes. Pacific Lutheran University students sampled Spanaway Creek in 1993-1994 and found water temperatures in excess of state standards (PCPWU 1997).

Spanaway Lake receives drainage from about 10,800 acres. About 180 houses on septic systems line the shores of the 28-acre lake, which is used heavily for recreation. In 1990, Ecology found that concentrations of dissolved oxygen were depleted in the bottom 10 feet of the lake largely due to decomposition of aquatic plant material and thermal stratification. The average total nitrogen concentration was 0.847 mg/L in June 1990. Total phosphorus ranged from 0.01 to 0.028 mg/L. Spanaway Lake has been chemically treated to control weeds, algae, and fish species (Rector and Hallock, 1993).

Lakes

Both Spanaway Lake and Tule Lake are instream lakes in the subbasin. Information available regarding these two lakes is included in the previous discussion.

Action Recommendations

The following salmonid habitat restoration actions are recommended for Spanaway Creek:

Fish Access:
- ◊ Conduct comprehensive fish passage barrier and priority index survey.
- ◊ Remove or replace identified high priority salmonid blockages, including the two mentioned previously in this document.

Floodplain Modifications:
- ◊ Determine the extent to which the constructed ponds affect the historic channel, and restore connection if determined to be beneficial.

Channel/Substrate:
- ◊ Restore stream to more natural system (sinuosity, habitat complexity, sediment delivery, etc., where possible throughout the stream.
- ◊ Increase channel complexity by addition of instream large woody debris (LWD) in appropriate areas.

Riparian:
- ◊ Maintain and protect existing functional riparian vegetation.
- ◊ Restore degraded riparian conditions through education and regulation. Use historic information and on-site surveys to restore with the appropriate native plant species, and consider the stream size for a functional riparian buffer.
- ◊ Eliminate non-native plants from riparian zones, and revegetate with native species.
- ◊ Reduce riparian wood removal, including removal by private citizens, through education and regulatory actions.

Water Quantity:
- ◊ Seek opportunities to reduce water withdrawals from the drainage.
- ◊ Explore methods of sealing ponds more effectively to prevent loss of water due to infiltration.
- ◊ Follow the recommendations that develop from the Watershed Planning (2514) process.

Sequalitchew Creek 12.0019

General

Sequalitchew Creek is an independent tributary entering the east bank of Puget Sound near the City of Dupont. It has its origins in Kinsey Marsh and flows west then northwest as Murray Creek before flowing into American Lake. Williams, et al (1975) reported that the historic connection between American Lake and Sequalitchew Lake has been eliminated and the connection between the two lakes is now underground. Fort Lewis officials report, however, that overflows from American Lake do flow to Sequalitchew Lake (Crown, Pers. comm., 2003). After leaving Sequalitchew Lake, the creek continues generally west until it reaches Puget Sound approximately 9.6 miles from its origins (Williams, et al 1975).

There is occasional disagreement over information published regarding the Sequalitchew Creek system between outside observers and Fort Lewis base officials. As in other sections of this report the authors have attempted to present all pertinent information, noting disagreement where found.

Fish Access

The creek enters saltwater south of the historical location of the Dupont Wharf (now removed), through a culvert under the existing dike supporting the Burlington Northern railroad tracks. The culvert opening is perched above the shoreline in a riprap-armored section. In extreme low flow events, adult salmon have been observed gathering and milling around the area in front of the culvert opening to Puget Sound. Fish are only able to move through the culvert on incoming high tides and sometimes disperse to other, larger freshwater systems in the area. In some years, salmon were known to mass spawn in the stretch of the creek upstream from the immediate mouth (Clothier, et al 2003).

Partial blockages resulting from beaver dams in the Edmond and Hamer Marsh reaches (RMs 0.6-2.6) hamper downstream smolt migration and later in fall combine with low flows to restrict adult migration to the outlet of Sequalitchew Lake (Clothier, et al 2003). A culvert under a historic railroad right-of-way also restricts the channel and subsequent water flow in the Edmond Marsh area (Whitman, Pers. comm., 2003).

Mills reported (Pers. comm., 1994) that a rotary screen and stop log structure form a barrier to anadromous fish at the outlet of Sequalitchew Lake, although Crown reports (Pers. comm., 2003) that these were removed in 1997.

A natural depression lies between Sequalitchew Creek and the diversion canal, just west of where the canal crosses the creek (Andrew and Swint 1994). Although Fort Lewis officials report (Crown, Pers. comm., 2003) that the natural depression described is not a connection between the Creek and the canal due to a diversion weir bisecting the depression, Andrew & Swint (1994) reported that when the water level in the creek is high, it can overflow into the canal via this natural depression. Water from the creek is thus unintentionally diverted into the canal. The effect of this diversion is not monitored during the winter months when the flow of the creek is at its highest, and most likely to overflow into the canal. In fact, it seems that the diverted flow is not considered an issue, except during salmon release. If water is diverted into the canal through the depression during the release, the fingerlings are diverted as well. Carried by the high flow of the creek, the salmon travel down the canal instead of down Sequalitchew Creek. The water in the canal reaches Puget Sound at Tatsolo Point, where it flows down a steep concrete flume. The descent down the flume is fatal to the delicate fingerlings. According to Darrell Mills of WDFW, they often reach the bottom of the flume scraped nearly bare of their protective scales (Andrew and Swint 1994).

In the upper basin, Murray Creek contains fish passage barriers in the form of reed canary grass. This plant grows in dense communities at I-5 and just downstream of I-5, and may impede fish passage during low flows (Shapiro 1996, cited in Clothier, et al 2003).

No comprehensive survey of fish passage barriers has been completed for this subbasin.

Floodplain Modifications

The Sequalitchew Creek watershed is undergoing a dramatic population increase. Population is currently a little over 20,000 people, and it is projected to increase to around 25,000 within the next 25 years (Whitman, et al 1999).

The extraction of sand and gravel at the Lone Star Mining operation has had an impact on the goals of the watershed, through the extraction of sand and gravel. DuPont city officials want to maintain the health and natural features of the creek, and have identified concerns about air, water and land quality from the mining. Some citizens of Dupont are concerned that the water may be polluted from industrial run-off and oil from the barges (Whitman, et al 1999).

Channel and Substrate Conditions

Sequalitchew Creek flows underneath the Burlington Northern-Santa Fe railroad tracks and directly into Puget Sound. Because of the stream gradient at the point of entry into Puget Sound there is very little estuary associated with this system. Rather, its importance is as a freshwater input along the northern shoreline in the vicinity of the Nisqually Reach.

In the upper reaches the stream has been channelized. As the stream leaves Sequalitchew Lake it flows for approximately 0.5 miles through a channel before skirting Hamer Marsh and entering Edmonds Marsh. This channelization limits the lateral movement of the creek within its natural floodplain. The creek then assumes a more natural channel before it passes through a large culvert under the railroad dike along the edge of Puget Sound. There is very little natural estuary present (Williams 1975, cited in Kerwin 2000).

No detailed studies have been completed on sediment quality within this basin. There is restricted opportunity for spawning in the lower reach due to limited gravel patches, but chum salmon have been observed spawning in the lower 200 feet (Williams 1975, cited in Kerwin 2000).

In the late 1970s, the stream was described as follows: The streambed habitat in Edmond Marsh may be characterized as a slowly flowing, deep, narrow channel with muddy organic substrate. West of Edmond Marsh, long glide-pool areas are interspersed with short riffle sections; creek substrate is made up of small gravel mixed with mud and sand. In the lower 1.5 miles where Sequalitchew Creek flows through a steep-sided ravine, descending over 200 feet in elevation, habitat is that of well-washed riffle areas with gravel substrate (Dice, et al 1979).

Riparian Condition

The creek lies almost entirely within the boundary of Ft. Lewis and the old DuPont Powder property now owned by the Weyerhaeuser Company. This ownership pattern has afforded the creek a certain amount of riparian habitat protection. The riparian habitat consists of large second growth conifers, heavy stands of blackberries, brush and marshes that are densely covered with exotic reed canary grass (Kerwin 2000). The swampy marshes are densely covered with natural tule weeds, cattails, devils club, salmonberry brush, and aquatic weeds. Parts of the creek and marsh lands are impenetrable from the thick growths (Williams 1975). The creek side is lined with red huckleberry, creeping buttercups, salmonberry and mosses. Second-growth Douglas firs, western hemlocks, and western red cedars populate the upper reaches of the canyon walls and the plateaus above (Andrews and Swint 1994).

Recently, there has been significant loss of riparian habitat near Center Drive due to construction activities by Weyerhaeuser (Whitman, Pers. comm., 2003).

In the upper basin, a small section of Murray Creek riparian cover outside of the boundaries of Fort Lewis was assessed by AES. Along this small section of Murray Creek, a high percentage of riparian cover was observed. Percent shade cover was determined to be 76% to 100% due to lack of urban development (Table 10: Data Summary of Murray Creek Riparian Corridor). This percentage parallels that of creek length with riparian cover, leading AES to conclude that a high percentage of the existing riparian cover offers shade for the creek (Clothier, et al 2003). Much of the creek was not visible on the aerial photos used for the evaluation, due to its location near Ft. Lewis.

Table 10: Data Summary of Murray Creek Riparian Corridor

	North Bank	**South Bank**
Approximate Reach Length	6,312 feet	6,312 feet
Percentage of Creek Length with Riparian Cover	5,354 feet 84.8%	5,354 feet 84.8%
Average Width of Riparian Corridor	196 feet	220 feet
Percent Shade Cover	**76%-100%**	

(Clothier, et al 2003)

Some riparian resoration efforts have taken place along Murray Creek (Figure 19: Planting site of riparian restoration project, March, 2000). Invasive vegetation was removed and native species were planted along a portion of the stream on Ft. Lewis property in March 2000.

Figure 19: Planting site of riparian restoration project, March, 2000
(Photo by Pierce Conservation District)

Water Quantity

The quantity of water flowing through the stream channel of Sequalitchew Creek has been greatly affected by the modifications that have been made to the natural hydrological processes of the stream. Foremost among these are the elimination of the historical connection between American Lake and Sequalitchew Lake, and the withdrawal of water from the springs at the upper end of Sequalitchew Lake by Ft. Lewis Army Base. The canal arrangement immediately downstream from the lake and the flow barriers in Edmond Marsh are also of great influence (Kerwin 2000).

The lower part of the Sequalitchew Creek basin begins at the east end of Sequalitchew Lake where the Department of the Army operates a pumping station adjacent to the northeast corner of the lake (Sequalitchew Springs). This pumping station is operated to supply irrigation, domestic and emergency water to areas of Ft. Lewis. Water withdrawal is greatest during summer months when base flow into Sequalitchew Creek is lowest. The creek exits the west end of the lake, and from this source on throughout its one-mile passage across Fort Lewis, Sequalitchew Creek is a low gradient and slow moving creek. An engineered drainage and diversion canal, located at the western end of the lake, diverts overflow from the creek into Puget Sound when the flow capacity of Sequalitchew Creek is exceeded. (For a diagram of the diversion canal, see Figure 4: Diagram of Diversion Dam / Canal Structure at Outlet of Sequalitchew Lake.) The weir is used to control the level of Sequalitchew Lake, which is necessary because of the small vertical separation of lake water and the springs. When the lake rises above the level of the backflow prevention weir, lake water flows into the springs, placing the water supply at risk. Fort Lewis prepared a lake-level management plan for Sequalitchew Lake in 1997. The objective of this management plan was to identify and recommend measures to minimize the risk of lake water intrusion into the springs. Since that time Fort Lewis Public Works has adopted the measures outlined in that plan (Kerwin 2000).

WDFW notes that the potential capacity of the creek to allow for spawning is severely restricted by the low summer flow and any successful returns that still occur are the exception rather than the rule (Andrews and Swint 1994).

Water quality issues (i.e.: temperature) in Sequalitchew Creek are directly linked to quantity of flow in this system. The beaver activity in Sequalitchew Creek and the stream gradient in the headwaters of the creek are the most important factors controlling lake level and consequently the volume and rate of water diverted over the outlet weir. The backwater conditions created by downstream beaver dams combined with a culvert under a historic railroad right-of-way in Edmond Marsh (Whitman, Pers. Comm., 2003), allow virtually no water to pass from the lake source to the creek. Without constantly clearing the stream channel, water continues to be held-up without flowing freely through Sequalitchew Creek (Kerwin 2000).

Andrews and Swint (1994) cited the Natural Resources Committee 1993 report that the Fort was withdrawing from five to fifteen million gallons per day from the lake for its consumption. This translated to approximately 9-27 cubic feet per second (cfs) being diverted from the Creek (Mills 1994, cited in Andrews and Swint 1994). Fort Lewis officials report however that the Fort does not currently draw any water from the lake (Crown, Pers. comm., 2003).

The Melchiors and McGreer study (cited in Andrews and Swint 1994) presented some information as to the effect of the diversion structure on Sequalitchew Creek flow. They stated that the diversion canal is a "…significant factor in the direct reduction of Sequalitchew Creek Discharge." The effect of the canal on storm water run-off to Sequalitchew Creek can be seen in the flow records taken in December 1977. Although this was a very low rainfall year, the ratio of flow between the Creek and the canal is clear: "Maximum instantaneous flow of the canal was [100.1 cfs], 12/10/77. Peak flow of creek five days later was only [19.81 cfs]. Fort Lewis officials consider this information to reflect a misunderstanding of the purpose and lack of physical connection between the creek and canal (Crown, Pers. comm., 2003).

The large, unmonitored (by Ecology) withdrawals from Sequalitchew Lake by Fort Lewis are certainly one of the major factors in the reduction of the flow. However, examination of the diversion structure may indicate that there are unintentional and unmonitored overflows and back flow into the canal (Andrews and Swint 1994). Fort Lewis officials disagree with this conclusion (Crown, Pers. comm., 2003).

Recorded stream flow in Sequalitchew Creek ranged from 0-20 cubic feet per second (cfs). Flows during the summer have dropped to zero in the past (including the summer of 1977); however, some water generally remains in the stream in most years (Thut, et al 1978).

Probably the most important single factor affecting Sequalitchew Creek habitat is that it occasionally dries up. This reduces the populations of species of stream animals that would be in an active aquatic stage during dry periods since only small pools remain as habitat (Hynes, 1972 cited in Dice 1979). In Sequalitchew Creek, Thut and others (1978) reported a reduction by 84 to 89 percent of the total number of invertebrates per unit area from June 6 to September 19, 1977 (Thut, et al 1978 cited in Dice 1979). (Stream flows for these dates were 3.32 cfs and 0.11 cfs for June 6 and September 19 respectively). Where water flow in Sequalitchew Creek is sufficient, the water quality is generally good (Cited in Dice 1979).

Major limiting factors affecting salmon production in this drainage include summer low flows, unregulated water withdrawals from Sequalitchew Lake by the U.S. Army to facilitate the needs of North Fort Lewis, and water quality. Low summer flows in the stream relate directly to the lake level which provides the sole water supply during dry periods. Large pumping facilities are located at Sequalitchew Springs near the head of the lake and are operated continuously to provide drinking water for the military installations. This rate of groundwater withdrawal may be impacting the level of the lake and, therefore, the summer water supplies to the creek (PCPWU 1997). Fort Lewis officials disagree with the conclusions drawn by this work (Crown, Pers. comm., 2003).

Water Quality

Sequalitchew Lake covers 80 acres and has a maximum depth of 15 feet. The lake is fed primarily from groundwater sources, including Sequalitchew Springs at the northeastern corner of the lake. The lake is located on Fort Lewis and is used for waterborne military training as well as recreational uses, including fishing and boating. The Washington Department of Fisheries operates Coho salmon rearing pens at the east end of the lake. Based on limited sampling conducted in 1980-81, the State Department of Social and Health Services (DSHS) reported that Sequalitchew Lake had elevated iron and manganese levels in 1980-1981 (Littler, et al 1981). Sampling conducted in 1993 found one unusually high pH measurement (9.6) in August. DO levels ranged from 6.14 mg/L to 12.6 mg/L. Ammonia, nitrate, and phosphorus levels were relatively high, with maximum concentrations of 0.815 mg/L, 1.84 mg/L, and 0.118 mg/L, respectively (Fort Lewis 1993, cited in Clothier, et al 2003).

The late 1970s and early 1980s were strong years for the Sequalitchew Lake program, with releases of up to two million fingerlings per year. However, the high quantities of nutrient-rich food required for the fish caused algae blooms in Sequalitchew Lake, dirtying the lake and depleting the oxygen supply (Trout 1994). For that reason, the number of fingerlings released in Sequalitchew Lake was drastically reduced: in April of 1994, the fish screen was raised to release only 250,000 Coho fingerlings from Sequalitchew Lake to Sequalitchew Creek (Mills 1994).

Andrews and Swint (1994) reported that storm water drainage directly contributed to water quality problems in this area.

After leaving Sequalitchew Lake, Sequalitchew Creek flows approximately 2.5 miles to Puget Sound. It flows through several large marshes downstream of the lake. The Northwest Landing development in the City of Dupont is located south of the creek. In 1977 temperatures ranged from 2.9 to 18.5°C. DO concentrations in the creek were fairly low near the headwaters due to the influence of the Edmond and Hammer marshes, but levels were good near the mouth of the creek. Water pH levels of 5.7 were found downstream of the marshes, probably due to tannic acids in the marshes. Phosphorous levels in the creek ranged from 0.009 to 0.117 mg/L, and nitrate levels ranged from 0.926 to 6.64 mg/L. The elevated nitrate may be due at least in part to input from the former Dupont explosives manufacturing facility located south of the creek. In July and August 1977, fecal coliform counts were low near the headwaters of the creek but were well above state standards near the mouth (PCPWU 1997, cited in Clothier, et al 2003), possibly due to beaver activity in the Edmond Marsh area.

In the early 1990s, data was collected by students from Steilacoom High School. Their readings indicated that the creek was still characterized by low pH levels. They took three readings of 6.0 from the creek which is below the state minimum of 6.5. Nitrate readings were fairly low with only one moderately high reading of 1.54 mg/L. All other readings ranged from 0 to 0.44 mg/L. Coliform levels on the creek were fairly high with levels ranging from 100 to 4420 organisms/100ml (Droege 1994, cited in PCPWU 1997).

A more recent study (Whitman, et al 1999), published by students at Pacific Lutheran University, found positive results in DO tests, temperature trends, and fair results for fecal coliforms:

> **Dissolved Oxygen:** The trend in recent years is: DO levels slightly above the state standard. Washington Administrative Code (WAC) sets standards for DO concentrations that are included when determining the classification of a freshwater stream. Sequalitchew Creek, a State Class AA stream, must have DO greater than 9.5 mg/L.

Temperature: The temperature measurements at the four sample sites demonstrated a positive trend in the stream's health. Over the last three years temperature has remained stable in the creek. The water temperatures fall within the state standard of less than 16 degrees Celsius, describing Sequalitchew Creek as an extraordinarily healthy stream. (6-10° Celsius).
Fecal Coliform: The trends over the last 22 years have shown that fecal coliform levels are typically above the state standards but mostly below 100 colonies/100 ml, the standard for drinking water (Mitchell and Stapp 1997). Washington State standards for a Class AA stream are 50 colonies/100ml.

Above American Lake:
Murray Creek is the only natural surface water tributary to American Lake. This 3.8-mile stretch of creek originates in Kinsey Marsh on the Fort Lewis Logistics Center and flows through Camp Murray before discharging into American Lake. Murray Creek was sampled for nutrient levels to determine the amount of nutrients that surface waters might be contributing to problems in American Lake. Samples taken in 1991 and 1992 found the water in Murray Creek to be of fairly good quality (PCPWU 1997).

Storm event sampling conducted in Murray Creek in the early 1990s found concentrations of total phosphorous ranging from 0.025 to 0.045 mg/L. The creek occasionally experienced total phosphorous concentrations of up to 93 mg/L. Total nitrogen concentrations in the creek ranged form 108 to 600 mg/L, amounts judged to be low to moderate (KCM Feb. 1993, cited in PCPWU 1997).

Dissolved oxygen concentrations ranged from 8.47 to 16.8 mg/L. KCM found these levels to be low and felt that they indicated the presence of excess organic material (KCM 1993, cited in PCPWU 1997).

Fecal coliform bacteria samples taken from this stream ranged from 0 to 160 organisms/100ml. A storm event sample taken on October 22, 1991, found a concentration of 1400 organisms/100ml. Out of 17 samples, fecal coliform levels exceeded state standards of 50 organisms/100ml six times (KCM 1993, cited in PCPWU 1997).

Lakes

Ecology found American Lake to be partially supporting wildlife and aesthetic beneficial uses. They cited pathogens and noxious aquatic plant growth as the causes for nonattainment (Ecology 2/1993, cited in PCPWU 1997).

Action Recommendations

Major limiting factors affecting salmon production in this drainage include summer low flows, unregulated water withdrawals from Sequalitchew Lake by the U.S. Army to facilitate the needs of North Fort Lewis, and water quality. Low summer flows in the stream relate directly to the lake level which provides the sole supply during dry periods. Large pumping facilities are located over springs near the head of the lake and are operated continuously to provide domestic and emergency water supplies for the military installations here. Storm water drainage contributes to water quality problems in this area. Beaver dams have created blockage problems in the marsh areas in past years (Williams 1975).

The following salmonid habitat restoration actions are recommended for Sequalitchew Creek:

Fish Access:
- ◊ Conduct comprehensive fish passage barrier and priority index survey.
- ◊ Remove or replace identified high priority salmonid-blocking culverts, dams, weirs or other blockages with fish-friendly alternatives, including the barriers at the outlet of Sequalitchew

Lake, at the railroad near the mouth of the creek, and at the culvert under the railroad right-of-way in Edmond Marsh.
- ◊ Alter the diversion canal near the outlet of Sequalitchew Lake to prevent crucial water loss during spawning season in the main channel, and to prevent loss of fingerlings in the canal.
- ◊ Investigate the possibility of working with Ft. Lewis to restore the historical connection between American Lake and Sequalitchew Lake in a manner passable for fish.
- ◊ Investigate options for dealing with beaver caused barriers in Edmond Marsh.

Floodplain Modifications:
- ◊ Work with landowners in the Sequalitchew Creek, American Lake, and Murray Creek watersheds to protect floodplain and riparian conditions.

Channel/Substrate:
- ◊ Restore stream to more natural system (sinuosity, habitat complexity, sediment delivery, etc., in the upper reaches of Sequalitchew Creek where it has been channelized.
- ◊ Increase channel complexity by addition of instream large woody debris (LWD) in appropriate areas.
- ◊ Reduce the invasion of reed canary grass in the Murray Creek channel.

Riparian:
- ◊ Maintain and protect existing functional riparian vegetation.
- ◊ Eliminate non-native plants from riparian zones, especially blackberry and reed canary grass, and revegetate with native species.
- ◊ Along American Lake and Murray Creek banks, Restore degraded riparian conditions through education and regulation.

Water Quantity:
- ◊ Encourage Ft. Lewis to reduce or eliminate water withdrawals from the springs in Sequalitchew Lake.
- ◊ Alter the diversion canal near the outlet of Sequalitchew Lake to prevent crucial water loss during spawning season in the main channel.
- ◊ Follow the recommendations that develop from the Watershed Planning (2514) process.

Water Quality:
- ◊ Improve water quality throughout the Clover Creek drainage by addressing the instream flow conditions. This is further described in its respective section.
- ◊ Reduce storm water runoff and urban pollution inputs into the drainage.
- ◊ Implement Best Management Practices to reduce nutrient runoff delivered to streams and lakes in the upper part of the drainage.
- ◊ Determine source of fecal coliform contamination and take steps to eliminate it.

Puget Creek 12.0001

<u>General</u>

Puget Creek is a small perennial stream, approximately 1,648 feet long, draining down Puget Gulch directly to the Northwest portion of Commencement Bay. It is formed by several springs, the seepage from three tributaries in the upper half of the stream, and flow from off-channel ponds and three small, year-round streams in the lower half (PCRS 2002).

Fish Access

Although no comprehensive survey of fish passage barriers has been completed for this creek, this is a short creek in length, and the following two barriers probably cover all of the blockages in the stream.

The creek enters salt water via a culvert under Ruston Way. The outfall from the culvert is similar to the situation at Sequalitchew Creek, being perched above the immediate shoreline. The shoreline in this area is a combination of sandy beaches, riprap, and concrete bulkheads. To migrate upstream, fish need to access the culvert opening on incoming high tides (Clothier, et al 2003).

A fish passage barrier exists in Puget Creek on private property, not far upstream from where the creek enters the final culvert. A permit is being obtained for its replacement with a fishway series of pools. Other culverts exist upstream of the barrier in question that might pose a problem to fish passage once the lower barrier is replaced (PCRS 2002, cited in Clothier, et al 2003).

Floodplain Modifications

The gulch has steep sides and 150 foot bluffs that extend from Tyler and 33rd to Cedar and 16th in Tacoma (Isensee, Pers. comm., 1994, cited in PCPWU 1997). The vegetation present is emerging Douglas fir and second growth hardwood. Large stumps are present, indicating an historic forest (PCPWU 1997). The conclusion can be drawn that though logging occurred along the stream in the past, the topography of the gulch prevents urban development from encroaching too closely in the upper two-thirds of the watershed.

Channel and Substrate Conditions

Data is lacking in this area.

Riparian Condition

Puget Creek has sufficient riparian corridor to provide almost complete cover along its length. The width of the riparian zone is also good and provides enough area to perform a high level of riparian function. Percent shade cover was determined to be 76% to100%. This percentage parallels that of the creek length with riparian cover, leading AES to conclude that a high percentage of the existing riparian cover offers shade for the creek. Puget Creek represents a creek with the closest percent shade cover of 100%. However, the aerial photo examination may be somewhat misleading in that it may have counted enhancement plantings that have not yet passed the three-year critical survivability period (PCRS 2002). Puget Creek Restoration Society (PCRS, 2002) has provided information that details the length of Puget Creek to be 1,648 feet. According to PCRS, the lower third of the creek has a poor riparian condition, while the upper two-thirds of the creek has good riparian condition (except for invasive vegetation) (Clothier, et al 2003).

Table 11: Data Summary of Puget Creek Riparian Corridor

	North Bank	South Bank
Approximate Reach Length	1,648 feet	1,648 feet
Percentage of Creek Length with Riparian Cover	1,605 feet 97.4%	1,632 feet 99.0%
Average Width of Riparian Corridor	341 feet	299 feet
Percent Shade Cover	**76%-100%**	

(Clothier, et al 2003)

A 1998 study by students from Clover Park Technical College of the Puget Creek riparian zone focused on the invasive species in the area (Runge, Kilgore, Solheim 1998). Their findings confirmed the information given by Clothier (2003). They determined that approximately 35% of the gulch is covered with invasive plants. They determined that the two invasive species of greatest concern to the area were Himalayan Blackberry (*Rubus discolor*) and ivy (*Hedera sp.*). Two other non-native species were also found to be well established in places: holly (*Ilex sp.*) and morning glory (*Ipomoea sp.*). They also found Japanese Knotweed (*Polygonum cuspidatum*) in a few places. They found watercress in the stream (*Rorippa nasturtium-aquaticum*), an invasive aquatic plant originally introduced from Europe (Hansen 1998, cited in Runge, et al 1998). This plant creates a monoculture, reducing the diversity of insects, resulting in less food for fish.

Species native to the riparian zone of Puget Creek (Runge, Kilgore and Solheim 1998):

> "The gulch naturally divides itself into three sections, lower, central, and upper, each with a slightly different balance in the ecosystem, reflecting the soil conditions. The lower section is approximately 800 feet long, starting at the trailhead on Alder Street. The dominate tree is alder (*Alnus rubra*), and the area has an abundance of moisture loving plants, including salmonberry (*Rubus spectabilis*).
>
> In the center section, from about 800 feet to 2200 feet, bigleaf maples (*Acer macrophyllum*) outnumber the alders in the canopy. A few western hemlock (*Tsuga heterophylla*) and red cedar (*Thuja plicata*) are mixed in. Indian plum (*Oemleria cerasiformis*) increases in abundance, and laurel and cascara (*Rhamnus purshiana*) are found. The floor of the gulch narrows considerably above 1300 feet.
>
> In the upper section, above 2200 feet, Douglas firs (*Pseudotsuga menziesii*) appear in the canopy, and become more frequent as you continue to move up the canyon. Plants and trees that prefer dryer conditions become more frequent. These include red huckleberry (*Vaccinium parvifolium*), salal (*Gaultheria shallon*), and Oregon grape (*Mahonia nervosa*)."

<u>Water Quantity</u>

Much of the natural flow in Puget Creek has been incorporated into a storm drainage system which runs the length of Puget Gulch (Isensee, Pers. comm. 1994, cited in PCPWU 1997).

<u>Water Quality</u>

Water quality samples were taken from Puget Creek on January 28, 1994. The samples from Puget Creek measured dissolved oxygen (DO), water temperature, and conductivity. The water temperature readings ranged from 7.6°C to 11.1°C and were all within WAC 173-201A standards for a Class A stream.

However, the dissolved oxygen readings ranged from 5.6 mg/L to 9.2 mg/L and the WAC requires at least 8 mg/L. Out of 15 samples, 9 were below WAC standards. Samples taken in the upper reaches of the creek were much more likely to have low dissolved oxygen levels (USFWS 1993, cited in PCPWU 1997).

A more recent report (Clothier, et al 2003) documents the results of water quality monitoring in Puget Creek by Stream Team volunteers over a number of years. Limited monitoring has also been conducted by the Puyallup Tribe of Indians, the City of Tacoma, and students from the Universities of Washington and Puget Sound. Puget Creek appears to generally have good water quality, with pH, DO, and temperatures meeting the Washington State Water Quality Class A Standard (See Table 2: Surface Water Quality Standards for Washington Class A Waters) (Chapter 173-201A WAC, cited in Clothier, et al 2003).

Riparian improvements leading to cooler water temperatures, and installation of log weirs in 1995 have contributed to higher concentrations of dissolved oxygen in the stream (Scott Hansen, Pers. comm., 2003).

Action Recommendations

The following salmonid habitat restoration actions are recommended for the Puget Creek watershed:

Fish Access:

◊ Remove or replace the culvert at the mouth of the creek and any other blockages with fish-friendly alternatives.

Floodplain Modifications:

◊ Work with residents of the lowest reach in the creek and volunteers to improve floodplain and riparian conditions.

Channel/Substrate:

◊ Restore stream to more natural system (sinuosity, habitat complexity, sediment delivery, etc., where possible.
◊ Increase channel complexity by addition of instream large woody debris (LWD) in appropriate areas.

Riparian:

◊ Maintain and protect existing functional riparian vegetation.
◊ Eliminate non-native plants from riparian zones, and revegetate with native species.

Water Quantity:

◊ Redirect uncontaminated runoff from the storm drainage system and into the watershed.

Water Quality:

◊ Improve water quality throughout the Clover Creek drainage by addressing the riparian and instream flow conditions. These are further described in their respective sections.
◊ Reduce industrial and urban pollution inputs, into the drainage.

Fifth Street Waterway (1226069471699)

General

The Fifth Street Waterway is a small, independent tributary entering the east bank of Puget Sound at a small estuary near the end of 5th Street in the City of Steilacoom. It originates in Farrell Marsh, and flows for approximately one mile northwest before entering Puget Sound (Marcantonio, Pers. comm., 2003).

Figure 20: Marc Marcantonio and Judy Runge take GPS readings at the mouth of the Fifth Street Waterway in Steilacoom (Photo by Pierce Conservation District)

Fish Access

Coho and Coastal Cutthroat have been documented in this stream. The presence of chum salmon is anecdotal and presumed (Marcantonio, Pers. comm., 2003).

Marcantonio (Pers. comm., 2003) reports barriers to fish passage at the following points:

- A culvert exists at the exit to the estuary, where Lafayette Street crosses the mouth of the stream, in a situation similar to Puget and Sequalitchew Creeks. Returning fish can access the stream only at high tide.
- A culvert where the stream passes under Gove Street meets WDFW criteria for barrier status.

Channel Conditions

The stream has been channelized in places in its upper-middle reach, which flows through a residential neighborhood (Marcantonio, Pers. comm., 2003).

Riparian Condition

The upper-middle reach, a residential neighborhood, is low in riparian cover. The headwaters and lower reach (below Gove Street) contain excellent riparian cover with a mixture of hardwoods and conifers in the lower reach, and conifers in the upper reach (Marcantonio, Pers. comm., 2003).

Water Quality

Water Quality data is unavailable for this stream.

Action Recommendations

The following salmonid habitat restoration actions are recommended for the Fifth Street Waterway:

Fish Access:

◊ Conduct comprehensive fish passage barrier and priority index survey.
◊ Remove or replace identified high priority salmonid-blocking blockages, including the culvert at the mouth of the creek and the culvert under Gove Street, with fish-friendly alternatives.

Channel/Substrate:

◊ Restore stream to more natural system (sinuosity, habitat complexity, sediment delivery, etc., where possible throughout the stream.
◊ Increase channel complexity by addition of instream large woody debris (LWD) in appropriate areas.

Riparian:

◊ Maintain and protect existing functional riparian vegetation.
◊ Restore degraded riparian conditions through education and regulation. Use historic information and on-site surveys to restore with the appropriate native plant species, and consider the stream size for a functional riparian buffer.
◊ Eliminate non-native plants from riparian zones, and revegetate with native species.
◊ Reduce riparian wood removal, including removal by private citizens, through education and regulatory actions.

Water Quality:

◊ Improve water quality throughout the Clover Creek drainage by addressing the riparian, instream flow, and wetland loss conditions. These are further described in their respective sections.
◊ Start a water quality monitoring program in the stream.

Gravelly Lake

General

Gravelly Lake is an isolated lake located in Lakewood between Steilacoom Lake and American Lake. Though hydrologically connected through groundwater to nearby water bodies, the lake has no stream connections to Puget Sound, so it is not included in this report.

ASSESSMENT OF HABITAT LIMITING FACTORS

The intent of HB 2496 and watershed restoration is to determine what stream restoration actions are appropriate to provide healthy, productive populations of salmon for future generations that will support sport, commercial, and tribal fisheries. This goal requires a higher standard of habitat protection than would be necessary to just ensure continued existence of the species. Although there remains some debate on specific habitat thresholds necessary for productive salmon habitat, there is broad consensus that salmon require:

- cool, clean, well-oxygenated water,
- instream flows that mimic the natural hydrology of the watershed, maintaining adequate flows during low flow periods and minimizing the frequency and magnitude of peak flows (storm water),
- clean spawning gravels not clogged with fine sediment or toxic materials,
- presence of instream pools that will support juvenile rearing and resting areas for returning adults,
- abundance of instream large woody debris, particularly large key pieces, that provide cover, create pools, and provide habitat diversity,
- free, unobstructed migration for juveniles and adults to and from the stream of origin,
- broad, dense riparian stands of mature native trees (preferably conifer, where historically present) that provide cover, shade, LWD recruitment, etc., and
- estuarine conditions that provide nearshore migration corridors and support production of prey organisms for juvenile outmigrants, as well as for juvenile salmonid rearing and for returning adults.

A more detailed discussion of the role of healthy habitat is included in a previous chapter of this report.

Salmonid Habitat Concerns

WRIA 12, including the Chambers-Clover Creek and the Sequalitchew watersheds, as well as several independent tributary streams, is one of the smallest WRIAs in Washington State. Though it only covers approximately 180 square miles, several of the streams in WRIA 12 are known to support anadromous salmonids and bull trout/Dolly Varden. In addition, WRIA 12 includes ~27 miles of marine shoreline that support local anadromous salmonid stocks, as well as salmonid stocks from other Puget Sound WRIAs.

The occurrence and severity of habitat limiting factors varies among watersheds within WRIA 12 and among reaches within individual watersheds. Combined, these limiting factors significantly reduce the salmonid productivity potential of these streams. Initial significant impacts date back to early European settlement (mid to late-1800s). Subsequent land use modifications (including agriculture and the increasing conversion to commercial/rural residential/urban development) have adversely impacted the quantity and quality of salmonid habitat, and accessibility to habitat in these streams. Current habitat condition has even been compromised by past well-intended actions to restore habitat, such as removal of large woody debris (LWD) to ensure fish passage and asphalt sealing of the stream channel, that are now known to have been very detrimental to habitat quality and diversity.

Commercial/residential development and agriculture have caused increased erosion and sedimentation; natural stream channels have been ditched and channelized, streambanks, streambeds, and shorelines have been diked and armored, and some streams have been completely confined within culverts to facilitate development. Portions of streambeds have been lined with asphalt to prevent waters loss through infiltration. Many roadway/railroad crossings of streams have created complete/partial barriers to anadromous salmonid migration, especially along the marine shoreline. Numerous small private dams have been built to create instream ponds, most of which are also barriers to fish migration. Roadways constructed along stream corridors and associated ditching/channelization constrict the natural floodplain and eliminate access to historic off-channel wetland habitats. Extensive historical floodplain wetlands have been ditched and drained, and converted to urban, commercial, or agricultural use.

Riparian conditions have not been surveyed using the criteria developed by the Washington Conservation Commission (Appendix B), but are estimated as fair/poor along many streams, or portions of streams. Riparian trees have been eliminated, and even in many areas with remaining woody riparian vegetation, historic conifer and deciduous presence has been eliminated (or is sparse), limiting bank stability, year-round canopy cover, and LWD recruitment potential. LWD is observed to be absent or severely lacking in many of the WRIA 12 streams, particularly large key pieces that are stable and capable of influencing channel form. Lack of LWD is also directly associated with low instream pool frequency and lack of deep pools that are critical for juvenile and resident salmonid rearing and adult salmonid holding and resting prior to spawning. Presence of high levels of fines in the substrate is noted for several streams, although quantitative substrate sampling is very limited for WRIA 12 streams.

Land use conversion from natural forested condition to residential/commercial/agricultural uses has resulted in filling of floodplain wetlands, compaction of soils, and increased impervious surface. These all contribute to increased magnitude and frequency of peak stream flows and reduced groundwater and wetland storage, reducing base flows. Land use conversion, coupled with the displacement of the historical stream channels and subsequent disruption of the natural streambed seal in many streams, has significantly altered channel stability and substrate condition. In order to maintain the integrity of streams, it is imperative to maintain natural hydrology and implement state-of-the-art storm water controls throughout developed watersheds.

Productivity potential is also positively influenced by ensuring healthy returns of adult salmonid spawners, whose carcasses provide the marine nutrient base that serves as the foundation of the food web for juvenile salmonids and other stream associated invertebrates, fish, and wildlife. Adult salmonid spawners have also been documented to influence the nature of channel substrate and even channel dimensions. Large numbers of spawning salmonids modify riverine habitat in ways beneficial to future generations of salmonids; loss of these functions contributes to further habitat degradation.

Estuaries provide critical rearing and transition habitat for salmonids as they move as juveniles from fresh to saltwater, and as adults from the marine environment back to freshwater. Marine nearshore areas support juvenile salmonid rearing and migration and production of food fish and other organisms on which salmonids prey. The estuarine and nearshore habitats of WRIA 12 are critically important for salmonids originating from the WRIA 12 streams, and for juvenile salmonids originating from other WRIAs in Puget Sound, including juvenile Chinook that are listed as Threatened under the Endangered Species Act. The habitat quality and natural physical processes of estuarine and nearshore environments have been severely impacted in WRIA 12. Nearshore habitat has been significantly altered due to extensive armoring and alteration of the marine shoreline, including the construction of a railroad bed along most of the marine shoreline.

Habitat Condition Rating

Composite habitat observations and data are summarized in Table 12: Assessment of Habitat Limiting Factors for Salmonid-Bearing Watersheds within WRIA 12, as representative habitat condition ratings (Good (G), Fair (F), and Poor (P)) by watershed, for each of the identified habitat elements in this report. The Salmonid Habitat Condition Rating Standards used to develop these habitat condition ratings are included for reference in Appendix B. Stream or reach-specific salmonid habitat information is provided, where available, in the Habitat Limiting Factors by Sub-Basin chapter.

Watershed/habitat elements for which insufficient information was available to make a habitat condition assessment are noted in Table 12 as Data Gap (DG). Although the majority of streams in WRIA 12 are readily accessible to spawner and habitat surveys, it is interesting that there is little known regarding habitat conditions in a large number of the watersheds. In addition, there are certain habitat elements, such as alterations to peak and base flows, water quality assessment, or substrate condition, where information is very limited, even for streams with the greatest amount of overall available habitat information.

The ratings in Table 12 generally represent the composite habitat condition for the anadromous accessible portion of each watershed; some reaches of a watershed may be better or worse. A range of habitat condition ratings is presented where there is significant habitat quality variation between reaches within a watershed. Many of the habitat condition ratings for these watersheds are based on qualitative observations and experience, due to the lack of quantitative habitat assessments for many of the watersheds in WRIA 12.

Action recommendations to address identified habitat limiting factors for each watershed are included in the Habitat Limiting Factors by Subbasin chapter. The common thread between the action recommendations is restoration of channel and floodplain ecological function (represented by "good" habitat ratings for each of the specific habitat elements). These functions are not only critical to restoring salmonid populations in these watersheds, but are also critical to other overall watershed functions in WRIA 12 (e.g., prevention of flooding impacts and maintaining water quality for instream and domestic use).

The purpose of Table 12 is to provide a quick visual reference to indicate the relative health and knowledge base of salmonid habitat in individual streams. For watersheds where habitat information is available, Table 12 also may provide a relative comparison of habitat condition within and among streams. However, caution is recommended when comparing watershed conditions due to the wide diversity in quality and quantity of habitat information and knowledge for each watershed. The summary information in Table 12 is useful as a general guide to habitat problem "hot spots" that warrant restoration consideration, or additional assessment data collection to guide habitat restoration. However, the Habitat Limiting Factors by Subbasin chapter should be consulted for specific stream information and action recommendations on which to base specific salmonid habitat restoration proposals. The potential benefit of proposed habitat restoration actions may be limited due to the number of habitat problems in a stream, higher priority limiting factors that should be addressed first, sequencing of projects to ensure effectiveness, etc.

Table 12: Assessment of Habitat Limiting Factors for Salmonid-Bearing Watersheds within WRIA 12

Stream	WRIA Index[2]	Fish Access	Floodplain Connectivity	Channel Conditions: LWD	Channel Conditions: Pools	Channel Conditions: Substrate	Riparian Condition	Water Quality[1]: Temp/ DO	Water Quality[1]: Toxics	Hydrology: Peak Flow	Hydrology: Low Flow	Estuarine
Puget Creek	12.0001	P	P	DG	DG	DG	F	G	G	DG	DG	P
Day Creek	12255954 72381	P	DG	DG	DG	DG	DG	DG	DG	DG	DG	NA
Chambers Creek	12.0007	P	F	DG	DG	DG	F	DG	P	DG	DG	G
Peach Creek	12253814 71972	P	P	DG	DG	DG	DG	DG	DG	DG	DG	NA
Leach Creek	12.0008	P	P	DG	DG	DG	F	DG	P	DG	DG	NA
Flett Creek	12.0009	P	P	DG	DG	DG	P	DG	F	DG	DG	NA
Steilacoom Lake	12.0007	P	P	NA	NA	NA	P	DG	P	DG	DG	NA
Clover Creek	12.0007	P	P	P	P	P	P	G	P	F	P	NA
Ponce de Leon Cr	12.0010	P	P	DG	DG	DG	DG	DG	P	DG	DG	NA
Morey Creek	12.0011	P	P	P	P	F	P	P/F	F	F	F	NA
Spanaway Creek	12.0012	P	P	DG	DG	DG	F	F/G	DG	F	F	NA
Spanaway Lake	12.0012	P	P	NA	NA	NA	DG	DG	DG	DG	DG	NA
Coffee Creek	12.0013	P	G	F	F	P	G	F	P	F	F	NA
NF Clover Creek	12.0014	P	P	P	P	F	P	DG	DG	DG	DG	NA
Unnamed	12.0015	P	P	DG	DG	DG	DG	DG	DG	DG	DG	NA
Sequalitchew Creek	12.0019	P	P	DG	DG	DG	F	F/G	DG	DG	DG	P
Sequalitchew Lake	12.0019	P	P	NA	NA	NA	DG	DG	DG	DG	DG	NA
American Lake	12.0019	P	P	NA	NA	NA	DG	DG	DG	DG	DG	NA
Murray Creek	12.0019	P	F	DG	DG	DG	G	DG	DG	DG	DG	NA
5th Street Waterway	12260694 71699	P	F	DG	DG	DG	F	DG	DG	DG	DG	G

(Good (G), Fair (F), Poor (P), Data Gap (DG), Not Applicable (NA)

[1] Several streams in WRIA 12 have tested positive for fecal coliform bacteria. Although fecal coliform listings are included in the individual watershed discussions in the Habitat Limiting Factors by Subbasin chapter, they are not included in watershed habitat ratings due to the lack of identified effects to salmonid habitat or survival.

[2] Thirteen digit numbers are based on LLID System, currently used by WDFW.

Habitat Restoration Potential

Despite the extensive impacts that have occurred to fresh and marine water habitats in WRIA 12, and the large number of fair, poor, or data gap habitat ratings that exist throughout the area, there are a number of reasons to be optimistic regarding the future of salmonid habitat and productivity in WRIA 12. Even though many of the land areas in the watersheds of WRIA 12 have been subject to significant encroachment by development, habitat restoration in and along the streams should be actively pursued, as these streams contribute to the overall productivity of South Puget Sound, and cumulatively contribute significant overall salmonid production. Restoration of estuarine and nearshore habitat is also critical, as these habitats are actively utilized by all salmonid species and stocks originating in WRIA 12, as well as stocks originating from other Puget Sound WRIAs. Habitat protection and restoration action recommendations for individual streams and estuarine/nearshore habitats are identified in the Habitat Limiting Factors by Subbasin chapter of this report. Habitat protection and restoration actions are suggested within each watershed area, but no suggestions have been offered regarding prioritization between watersheds. Cross-watershed protection/restoration prioritization is considered to be the purview of the WRIA 12 Lead Entity.

Restoration projects in WRIA 12 should be considered in relation to the production potential of the stream and the anticipated benefits. Some streams have areas where habitat is currently in relatively good condition, and these areas should be protected. Other degraded habitats have potential to provide excellent habitat and warrant special consideration. Unfortunately, the habitat in many of the WRIA 12 streams (particularly those in densely developed watersheds) has been severely impacted, limiting the potential benefits of restoration.

HABITAT NEEDING PROTECTION

Previous chapters in this report identify salmonid habitat limiting factors throughout WRIA 12 (resulting from adverse impacts caused by the broad suite of land use practices that exist in the watershed), which would benefit from habitat restoration projects. However, there are a few habitat areas that remain in relatively good condition, where existing habitat functions should be protected, or where acquisition/easement is considered critical to future restoration success. These areas serve as the foundation upon which habitat restoration and salmonid recovery efforts are most effectively built. Protection of functional salmonid habitat is typically more cost effective and provides greater certainty of long-term success than restoration of degraded habitat. Habitat protection can be provided through acquisition, conservation easement, or specific protection under critical area ordinances or other regulatory processes administered by local land use managers.

It is not practicable to prioritize areas recommended for acquisition or conservation easement, as opportunities often only arise as willing sellers surface, with typically a very limited timeframe in which to respond. Efforts should be initiated to identify critical stream reaches and/or protection strategies to ensure continued function of high quality salmonid habitat, or areas that are critical to restoration of natural floodplain function.

Coho, chum, and steelhead spawner counts and densities may assist in identifying streams/reaches of key importance, but it is likely also important to look at additional watersheds that may not be adequately represented in the spawner count database. It is also important to consider relative risk to current habitat and the need for acquisition/conservation easement to facilitate habitat protection/restoration efforts.

Opportunities for public acquisition of key habitats should be evaluated and exercised where warranted; public ownership offers greater potential for protection and restoration.

Protecting existing habitat function is far more cost effective and provides greater certainty than attempting to restore lost habitat function. Federal and state forest management regulations are anticipated to reduce past adverse affects to salmonid habitat, and lead to natural restoration of habitat conditions over time. County and local development regulations should be reviewed and modified as necessary to ensure that they adequately protect critical areas and salmonid habitat functions, and implemented to ensure that the desired habitat protection is achieved. All salmonid habitats should be included within local critical areas ordinances, and those ordinances should be reviewed and revised as necessary to ensure no further degradation of salmonid habitat, and to restore habitat function where possible.

DATA GAPS

Many important factors relating to salmon habitat in WRIA 12 have not been adequately studied. These factors impact Chambers-Clover salmon in all fresh water life stages, and impact other Puget Sound salmon stocks as well in the marine nearshore environment.

Unlike many marine nearshore habitat areas in Puget Sound, no comprehensive assessment of habitat conditions has commenced. This study should include a WRIA-wide study of the presence and importance of eelgrass beds. The Burlington Northern rail-line along the west shore of mainland WRIA 12 has extensively filled in estuarine habitat and degraded natural processes along the shoreline, likely imposing significant limitations upon Chambers-Clover salmon, as well as Nisqually River Chinook migrating to and from their home river. Studies to determine the feasibility and potentially positive impacts of replacing the extensive shoreline armoring with more salmon-friendly materials as well as restoring the historical estuarine habitat should be conducted.

The entire freshwater system has been extensively modified by human development. Much of this modification has included culverts and dams, which often impose partial or full barriers to salmon migration. Some barrier removal projects have already been conducted, but no watershed wide barrier study has taken place, leading to the possibility that projects are being constructed with downstream barriers still in place. A comprehensive watershed barrier and priority index study would determine the feasibility of opening access to the stream system to salmon, and help local governments focus their attention on removing the barriers in the most cost-effective manner possible, as well as preventing barrier removals upstream of other unknown barriers.

The storm water "first flush" phenomenon has been associated with significant water quality problems impacting WRIA salmon, and may have led to the documented fish kill in 1993 (see Appendix D). As previously noted, WRIA 12 has been significantly impacted by the urban environment, and pollutants are to be expected in such densely human populated areas. Further study could potentially identify methods to mitigate the effects of "first flush" in this and other urbanized stream systems, however. These methods may include better oil-water separation, enhanced storm water detention and retention systems, and coordinated public outreach programs to increase knowledge of human habitation and its impacts on nearby natural systems. A study of the presence and causes of the first flush phenomena should be conducted to determine these impacts and potential corrective measures.

The subject of water loss in Clover Creek is discussed at length throughout the report. Most observers believe that the creek carried perennial flows historically, and that the system's ability to maintain water flow for salmon usage has been negatively impacted by human development. This issue has not been confirmed through scientific field study however, and warrants further attention not only to ensure adequate water flows for salmon, but to prevent potential flooding in other areas through the redirection of groundwater. If, in fact, the creek has a fragile "seal" due to the limited presence of organics in the stream flow, and if this seal is subject to breakage during land development or instream construction, research should be conducted to determine the best methods to restore a stream seal in the creek.

Substantial areas of Clover Creek are thought to be negatively impacted by the presence of fecal coliform bacteria, emanating from livestock bearing properties. Fecal coliform and associated bacteria can be detrimental to salmonids, and unrestricted livestock access to streams can cause erosion and other harmful conditions. No comprehensive inventory of livestock bearing properties has been conducted in this WRIA. Knowing the location and density of livestock loads in the WRIA could be an important first step in the development of a strategy to reduce these negative impacts upon the creek. A comprehensive inventory of the location and density of livestock populations in the WRIA should be conducted.

No information was found on Day Creek, LLID 1225595472381, an independent tributary flowing into Puget Sound near Day Island, though this creek has presumed or known distribution of cutthroat trout.

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ACRONYMS AND ABBREVIATIONS USED IN THIS REPORT

The following list provides a guide to acronyms and abbreviations used in this report:

AES	Applied Environmental Services, Inc.
AFB	Air Force Base
BMP	Best Management Practices
BPA	Bonneville Power Administration
cfs	cubic feet per second (a measure of water flow)
CMZ	Channel Migration Zone
CSO	Combined Sewer Overflow
CW	Channel width
CWA	Clean Water Act
dbh	diameter breast height (measurement of tree diameter)
EF	East Fork
ESA	Endangered Species Act
IFIM	Instream Flow Incremental Methodology
LB	Left Bank (looking downstream)
LWD	Large Woody Debris
m	meter
MF	Middle Fork
mgd	million gallons per day
mg/L	milligrams/Liter
mi	mile
mi^2	square miles
NF	North Fork
NRCS	Natural Resource Conservation Service
NWIFC	Northwest Indian Fisheries Commission
ppm	parts per million
RB	Right Bank (looking downstream)
RM	River Mile
SASSI	Salmon and Steelhead Stock Inventory
SF	South Fork
SPTH	Site Potential Tree Height
SSHIAP	Salmon and Steelhead Habitat Inventory Assessment Project
SSI	Salmonid Stock Inventory
TAG	Technical Advisory Group
TFW	Timber, Fish, and Wildlife
TSS	Total Suspended Solids
ug/L	micrograms per liter (10^{-6})
USFS	U.S. Forest Service
USGS	United States Geological Survey
WAC	Washington Administrative Code (rules implementing state statutes)
WADNR	Washington State Department of Natural Resources
WDFW	Washington State Department of Fish and Wildlife
WF	West Fork
WRIA	Water Resource Inventory Area
WSDOT	Washington State Department of Transportation
WWTIT	Western Washington Treaty Indian Tribes

APPENDICES

APPENDIX A

CHAMBERS/SEQUALITCHEW CREEK (WRIA 12) SALMONID DISTRIBUTION

The following streams in Chambers/Sequalitchew Creek watershed (WRIA 12) are identified as having anadromous salmonid presence:

Chambers Creek
Clover Creek
Leach Creek
Flett Creek
Ponce de Leon Creek
Morey Creek
Spanaway (Coffee) Creek
Sequalitchew Creek
Puget Creek
Fifth Street Waterway
Day Creek

Known distribution (code=1 in species column) in these streams represents current knowledge, which is limited to those streams/locations where observations of adult or juvenile salmonids have been made. Known distribution may be significantly different than historic distribution, with current distribution likely being more limited. Reasons for more restricted current distribution include habitat conditions that no longer support salmonids; presence of barriers that preclude salmonid access to productive habitats; and reduced spawner populations that tend to narrow the distribution extent, limit the ability of the fish to maintain suitable substrate conditions, and limit the return of marine nutrients from carcass decomposition that support the instream food web for subsequent juvenile salmonid production. Actual distribution may be greater than represented, as known distribution only includes areas where observations of fish have been made, and there are numerous tributaries in the watershed where comprehensive assessment of salmonid presence has not been conducted.

Presumed species distribution (code=2 in species column) is also identified for a number of streams and species. Presumed distribution typically represents streams/reaches with known distribution downstream and sufficient knowledge of habitat conditions to estimate that distribution of the species likely extends upstream through suitable habitat to an identified migration barrier (natural or anthropogenic).

Potential/historic distribution (code=3 in species column) is identified where historic distribution is known/presumed to have been more extensive based on watershed literature, personal knowledge, or presence of suitable salmonid habitat upstream of anthropogenic fish passage barriers. Potential/historic salmonid distribution is also likely greater than represented.

Artificial distribution (not represented in table or distribution maps) represents areas above natural barriers that were not historically accessible to anadromous salmonids, but which are now accessible due to fishways or trap and haul operations.

See WRIA 12 watershed species distribution maps for a visual representation of the data in the Salmonid Distribution Table. More detailed GIS data is available from the Northwest Indian Fisheries Commission. Stream index numbering (except where noted) and river mile designations are based on that presented in the WDF Stream Catalog – Puget Sound Volume 1 (Williams, et al 1975).

Table 13: WRIA 12 Salmonid Distribution Table

Stream Name	Stream No. [1]	Species [3] Chin	Chum	Coho	Sthd	Pink	Sock /Kok	Cutt	Extent (RM)[2]	Comments
Puget Creek	12.0001			1				1	0.2	
Day Creek	1225595472381							2	0.4	Presumed cutthroat distribution
Chambers Creek	12.0007	1/3	1	1	1	1	1/3	1	4.1	Distribution extends entire length of stream (except Chinook, pink, sockeye, Kokanee)
Leach Creek	12.0008	3	1	1	1			1	1.9	Coho/chum distribution to 53rd St. W.
Flett Creek	12.0009	3	1	1	1			1	2.0	Presumed Coho distribution to flow control ponds
Clover Creek	12.0007	3	1	1	3		3/1	1	18.6	Coho distribution to near 60th Ave. E, Graham
Ponce de Leon Creek	12.0010			1	3		3/1	1	UA	Coho distribution extends entire length of stream
Morey Creek	12.0011			1				1	1.0	Coho distribution extends entire length of stream
Spanaway Creek	12.0012			1/3				1	5.5	Historic/potential Coho distribution extends entire length
Spanaway Lake	12.0012			3				1		Historic/potential Coho distribution extends entire length
NF Clover Creek	12.0014			1				1	3.2	Presumed Coho distribution entire length of stream
Unnamed	12.0015			2				1	2.75	Presumed Coho distribution entire length of stream
Fifth Street Waterway	1226069471699			1				1/2	0.3	Presumed Coho distribution to culvert at Gove St., presumed cutthroat entire length
Sequalitchew Creek	12.0019		3	1				1	3.1	Coho distribution to outlet of Sequalitchew Lake
Sequalitchew Lake	12.0019			2				1	4.0	Presumed Coho distribution extends entire length
American Lake	12.0019									Historic connection to Sequalitchew Cr. is severed
Murray Creek	12.0019							1	9.6	Cutthroat distribution to Kinsey Marsh

[1] Thirteen digit numbers are based on the LLID System, currently used by WDFW. [2] RM are estimates, and are based on presumed distribution.
[3] 1= Known Distribution, 2 = Presumed, 3 = Historic/Potential, and 4 = Artificial Ditribution. A combination (i.e., 1/3) reflects multiple distribution conditions within a stream.

APPENDIX B

SALMONID HABITAT CONDITION RATING STANDARDS FOR IDENTIFYING LIMITING FACTORS

Under the Salmon Recovery Act (passed by the legislature as House Bill 2496, and later revised by Senate Bill 5595), the Washington Conservation Commission (WCC) is charged with identifying the habitat factors limiting the production of salmonids throughout most of the state. This information should guide lead entity groups and the Salmon Recovery Funding Board in prioritizing salmonid habitat restoration and protection projects seeking state and federal funds. Identifying habitat limiting factors requires a set of standards that can be used to compare the significance of different factors and consistently evaluate habitat conditions in each WRIA throughout the state.

In order to develop a set of standards to rate salmonid habitat conditions, several tribal, state, and federal documents that use some type of habitat rating system (Table A) were reviewed. The goal was to identify appropriate rating standards for as many types of habitat limiting factors as possible, with an emphasis on those that could be applied to readily available data. Based on the review, it was decided to rate habitat conditions into three categories: Good, Fair, and Poor. For habitat factors that had wide agreement on how to rate habitat condition, the accepted standard was adopted by the WCC. For factors that had a range of standards, one or more of them were adopted. Where no standard could be found, a default rating standard was developed, with the expectation that it will be modified or replaced as better data become available.

Table A - Source documents

Code	Document	Organization
Hood Canal	Hood Canal/Eastern Strait of Juan de Fuca Summer Chum Habitat Recovery Plan, Final Draft (1999)	Point No Point Treaty Council, Skokomish Tribe, Port Gamble S'Klallam Tribe, Jamestown S'Klallam Tribe, and Washington Department of Fish and Wildlife
ManTech	An Ecosystem Approach to Salmonid Conservation, vol. 1 (1995)	ManTech Environmental Research Services for the National Marine Fisheries Service, the US Environmental Protection Agency, and the US Fish and Wildlife Service
NMFS	Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast (1996)	National Marine Fisheries Service
PHS	Priority Habitat Management Recommendations: Riparian (1995)	Washington Department of Fish and Wildlife
Skagit	Skagit Watershed Council Habitat Protection and Restoration Strategy (1998)	Skagit Watershed Council
WSA	Watershed Analysis Manual, v4.0 (1997)	Washington Forest Practices Board
WSP	Wild Salmonid Policy (1997)	Washington Department of Fish and Wildlife

The ratings adopted by the WCC are presented in Table B. These ratings are not intended to be used as thresholds for regulatory purposes, but as a coarse screen to identify the most significant habitat limiting factors in a WRIA. They also will hopefully provide a level of consistency between WRIAs that allows habitat conditions to be compared across the state. However, for many habitat factors, there may not be sufficient data available to use a rating standard or there may be data on habitat parameters where no rating standard is provided. For these factors, the professional judgment of the TAG should be used to assign the appropriate ratings. A set of narrative standards will be developed in the near future to provide guidance in this situation.

In some cases there may be local conditions that warrant deviation from the rating standards presented here. This is acceptable as long as the justification and a description of the procedures that were followed are clearly documented in the limiting factors report. Habitat condition ratings specific to streams draining east of the Cascade crest were included where they could be found, but for many parameters they were not. Additional rating standards will be included as they become available. In the meantime, TAGs in these areas will need to work with the standards presented here or develop alternatives based on local conditions. Again, if deviating from these standards, the procedures followed should be clearly documented in the limiting factors report.

Table B - WCC salmonid habitat condition ratings

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Access and Passage						
Artificial Barriers	% known/potential habitat blocked by artificial barriers	All	>20%	10-20%	<10%	WCC
Floodplains						
Floodplain Connectivity	Stream and off-channel habitat length with lost floodplain connectivity due to incision, roads, dikes, flood protection, or other	<1% gradient	>50%	10-50%	<10%	WCC
Loss of Floodplain Habitat	Lost wetted area	<1% gradient	>66%	33-66%	<33%	WCC
Channel Conditions						
Fine Sediment	Fines < 0.85 mm in spawning gravel	All – Westside	>17%	11-17%	≤11%	WSP/WSA/ NMFS/Hood Canal
	Fines < 0.85 mm in spawning gravel	All – Eastside	>20%	11-20%	≤11%	NMFS
Large Woody Debris	pieces/m channel length	≤4% gradient, <15 m wide (Westside only)	<0.2	0.2-0.4	>0.4	Hood Canal/Skagit
	or use Watershed Analysis piece and key piece standards listed below when data are available					
	pieces/channel width	<20 m wide	<1	1-2	2-4	WSP/WSA

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	key pieces/channel width*	<10 m wide (Westside only)	<0.15	0.15-0.30	>0.30	WSP/WSA
	key pieces/channel width*	10-20 m wide (Westside only)	<0.20	0.20-0.50	>0.50	WSP/WSA
	* Minimum size to qualify as a key piece:	BFW (m) Diameter (m) Length (m) 0-5 0.4 8 6-10 0.55 10 11-15 0.65 18 16-20 0.7 24				
Percent Pool	% pool, by surface area	<2% gradient, <15 m wide	<40%	40-55%	>55%	WSP/WSA
	% pool, by surface area	2-5% gradient, <15 m wide	<30%	30-40%	>40%	WSP/WSA
	% pool, by surface area	>5% gradient, <15 m wide	<20%	20-30%	>30%	WSP/WSA
	% pool, by surface area	>15 m	<35%	35-50%	>50%	Hood Canal
Pool Frequency	Channel widths per pool	<15 m	>4	2-4	<2	WSP/WSA
	Channel widths per pool	>15 m	-	-	chann width / pools/ mile / cw/ pool 50' 26 4.1 75' 23 3.1 100' 18 2.9	NMFS
Pool Quality	pools >1 m deep with good cover and cool water	All	No deep pools and inadequate cover or temperature, major reduction of pool volume by sediment	Few deep pools or inadequate cover or temperature, moderate reduction of pool volume by sediment	Sufficient deep pools	NMFS/WSP /WSA
Streambank Stability	% of banks not actively eroding	All	<80% stable	80-90% stable	>90% stable	NMFS/WSP

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Sediment Input						
Sediment Supply	$m^3/km^2/yr$	All	> 100 or exceeds natural rate*	-	< 100 or does not exceed natural rate*	Skagit
	* Note: this rate is highly variable in natural conditions					
Mass Wasting		All	Significant increase over natural levels for mass wasting events that deliver to stream	-	No increase over natural levels for mass wasting events that deliver to stream	WSA
Road Density	mi/mi^2	All	>3 with many valley bottom roads	2-3 with some valley bottom roads	<2 with no valley bottom roads	NMFS
	or use results from Watershed Analysis where available					
Riparian Zones						
Riparian Condition	riparian buffer width (measured out horizontally from the channel migration zone on each side of the stream) riparian composition	Type 1-3 and untyped salmonid streams >5' wide	<75' or <50% of site potential tree height (whichever is greater) OR Dominated by hardwoods, shrubs, or non-native species (<30% conifer) unless these species were dominant historically.	75'-150' or 50-100% of site potential tree height (whichever is greater) AND Dominated by conifers or a mix of conifers and hardwoods (≥30% conifer) of any age unless hardwoods were dominant historically.	>150' or site potential tree height (whichever is greater) AND Dominated by mature conifers (≥70% conifer) unless hardwoods were dominant historically	WCC/WSP
	buffer width riparian composition	Type 4 and untyped perennial streams <5' wide	<50' with same composition as above	50'-100' with same composition as above	>100' with same composition as above	WCC/WSP

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	buffer width riparian composition	Type 5 and all other untyped streams	<25' with same composition as above	25'-50' with same composition as above	>50' with same composition as above	WCC/WSP
Water Quality						
Temperature	degrees Celsius	All	>15.6° C (spawning) >17.8° C (migration and rearing)	14-15.6° C (spawning) 14-17.8° C (migration and rearing)	10-14° C	NMFS
Dissolved Oxygen	mg/L	All	<6	6-8	>8	ManTech
Hydrology						
Flow	hydrologic maturity	All	<60% of watershed with forest stands aged 25 years or more	-	>60% of watershed with forest stands aged 25 years or more	WSP/Hood Canal
		or use results from Watershed Analysis where available				
	% impervious surface	Lowland basins	>10%	3-10%	≤3%	Skagit
Biological Processes						
Nutrients (Carcasses)	Number of stocks meeting escapement goals	All Anadromous	Most stocks do not reach escapement goals each year	Approximately half the stocks reach escapement goals each year	Most stocks reach escapement goals each year	WCC

APPENDIX C

Intermittent Flow On Clover Creek: Causes and Possible Solutions

Dept of Ecology (Sinclair and Carter 1986)

Abstract:
In August of 1984, the Washington State Department of Ecology undertook an investigation to identify the causes and possible solutions for intermittent flow through portions of Clover Creek. The Clover Creek basin encompasses 38,249 acres and is for the most part underlain by thick deposits of coarse permeable gravel.

Through time, silt and organic debris accumulated on the gravel bed of Clover Creek to form a natural "seal" that inhibited seepage. Up until the late 1800's, this fragile seal remained intact, and the creek flowed perennially. Since then, dredging, rechanneling, and other modifications to the creek channel caused disruption of this seal. The cumulative effect of such modification was readily apparent by the early 1940's, when Clover Creek ceased to flow year round through its central 3.15 miles. A number of pump diversions and the construction of more than 20 creek fed ponds throughout the basin since the 1940's further aggravated the problem.

Investigation
With the exception of the North Fork drainage, the Clover Creek basin is underlain by 10 to 60 foot thick deposits of Steilacoom gravel. Where the creek bed is undisturbed, a natural seal of silt and organic debris inhibits water loss due to percolation. It is a fragile system. When the creek bed is disturbed by dredging, rechanneling, or other activities and the seal is broken, water loss results. The eastern portion of the basin is relatively undisturbed. Water loss there is minimal. The central, intermittent and western portions of the basin are characterized by many disruptions and much water loss.

Eastern Segment
Between its headwaters and the Brookdale Golf Club, Clover Creek flows through a narrow, densely vegetated stream valley. The valley floor is underlain by thick deposits of Steilacoom gravel.

Twelve to twenty-four inch deposits of Dupont muck, Tisch silt loam, and Semiahmoo muck soil overlie the gravel throughout much of the valley. These soils, when thoroughly wetted, form a relatively impermeable barrier to the passage of water. Where they have not been removed or disarranged, they inhibit surface water seepage into the underlying gravel.

Pre-1940
The only known, large scale modification in the eastern Clover Creek valley occurred in the early 1900's when a canal was dug adjacent to Clover Creek to supply potable water to the city of Tacoma. From its beginning one quarter mile below the Old Military Road crossing of Clover Creek, the canal extends for approximately one half mile along the base of the hill that borders Clover Creek to the west. Although never used for its intended purpose, the canal carries roughly half of the present flow of the creek in its gravel bottomed channel.

Losses
It is not possible to measure the water lost by seepage from the canal, due to the abundance of spring water entering at several locations along its length. Given an estimated depth to groundwater of 20 feet,

(Brown and Caldwell 1983) and the high permeability of the underlying sediments, it is certain some water is lost by seepage from the canal.

Post-1940
At least six creek-fed ponds were constructed in the eastern portion of the Clover Creek valley since 1940. Only one of the ponds is effectively sealed. The remaining ponds are bottomed by grave and range in depth from 3 to 8 feet. They lie within the unsaturated gravel overlying the water table.

Losses
The lack of suitable measuring locations made it impossible to accurately determine the difference between the inflow and the outflow of the six ponds. The observed inflow was greater than the outflow for all but one of the ponds.

Central Segment
Like the eastern segment, the central segment of the basin is underlain by thick deposits of Steilacoom gravel. The impermeable topsoil found in the eastern portion of the basin does not occur here, however. In its place are 12 to 24 inch deposits of Spanaway gravelly sandy loam soil. This soil offers little resistance to seepage of surface water into the underlying gravel.

Pre-1940
Sometime prior to 1940, [possibly around 1895 (Tobiason 2003)], a large hop farm was established between the present day Brookdale Golf Club and 138th Street. During development of the farm approximately one mile of the creek was rechanneled into two large irrigation channels which lie on either side of the valley. Although the farm is no longer in operation, the irrigation channels still carry the flow of Clover through this reach.

The majority of Clover Creek is carried in the southerly most channel. At its eastern end, thick deposits of organic silt cover the gravel bed of the channel. A few hundred feet to the west the silt gives way to expose a bed of coarse gravel that continues through to 138th Street. In several places the channel banks have been breached by burrowing muskrats or the uprooting of trees. Where this occurs, the uncontained flow forms small marshes adjacent to the creek. The northerly most channel carries the remainder of Clover Creeks flow through this reach. It has similar losses to those noted on the southerly channel.

Losses
Flow measurements in August 1984 at either end of the southerly most channel show approximately 4.50 cubic feet per second (cfs) of water is lost from the channel over its one mile length. There are two primary causes of this loss. The most obvious loss results when water escapes through breaks in the channel bank as happens at several locations near the eastern end of the channel. Less obvious but far more prevalent is loss of water by seepage through the gravel bed of the creek. For example, a loss of 2.10 cfs was measured over one 1900 foot length of the channel. This loss can only be attributed to seepage through the channel bottom, since there are no pump or pond diversions and no obvious breaches of the channel banks along this reach.

Post 1940
Substantial water loss was observed near the eastern end of the northerly channel where the creek is diverted to maintain four man-made ponds. A loss of 2.6 cfs was measured over the 600 foot length of channel spanned by the ponds. About 19 percent of this loss (0.50 cfs) is attributable to seepage through the channel bed. The remainder is attributable to evaporations a seepage from the ponds.

Conclusions

A total of 8.57 cfs of water is lost from Clover Creek through its central portion. This loss is generally the result of two processes: seepage loss through the creek bed or through the bottom of creek fed ponds, and loss through breaks in the creek bank.

Intermittent Segment
Much of the intermittent segment of Clover Creek has been dredged or realigned since 1940. Evidence of this modification is particularly apparent west of Pacific Avenue. In 1967, a portion of the natural creek channel which extended from the intersection of Pacific Avenue and Brookdale Road, through Pacific Lutheran University Campus and west to the boundary of McChord AFB was abandoned. At that time, the flow of the creek was diverted to a dug ditch extending west for one and a half miles along the Tule Lake Road. Because it was excavated in Steilacoom gravel, considerable water was lost through the ditch bottom. It has since been lined with asphaltic concrete to inhibit water loss.

The North Fork of Clover Creek was extensively modified during the urbanizing of Parkland and Midland. Today it is little more than a series of deep interconnected roadside ditches. South of Brookdale Road the creek was dredged and its banks lined with concrete slabs to prevent erosion.

Impact
The North Fork of Clover Creek has historically been intermittent in nature. It is nearly impossible therefore, to determine if any cause and effect relationship exists between modifications to the creek channel and water loss from the creek.

With the exception of a trickling flow in the North Fork drainage near Brookdale Road, no water was observed in the intermittent portion of the basin during our initial field investigation in August of 1984. A follow-up investigation was made on November 14, 1984, after an extended period of heavy rainfall.

The only portion of Clover Creek not containing water during the follow-up investigation was the segment between 138th Street and 134th Street. Rarely, if ever, according to the residents living there, does the creek flow through this reach, even during peak winter flows. The lack of a defined stream bed and an abundance of vegetation along this reach are primary contributors to this problem. Any hope of establishing year round flow through this segment may require that the creek be dredged and lined with concrete. At the very least, the vegetation should be removed and some sort of creek channel established.

No pump or pond diversions were found in the intermittent segment of the basin.

Western Segment
Much of the western segment of Clover Creek was widened and deepened during the 1930's and early 1940's to help alleviate winter flooding problems. Within the borders of McChord AFB, Clover Creek and the western 2,000 feet of Morey Creek was dredged to a depth of about 12 feet. A natural overflow channel extending from the McChord western boundary to Ponce De Leon Creek was abandoned when the present day channel was widened and deepened. Approximately 4.0 miles of the creek were dredged during this project.

Most of the water loss in the western segment is the result of percolation through dredged portions of the creek bed. To effectively control percolation loss the creek bed needs to be artificially sealed or lined.

APPENDIX D

Fledgling Coho run killed

Biologists suspect urban pollution in deaths of salmon spawning in Clover Creek

By Sandi Doughton

Tacoma News Tribune, December 4th, 1993

The fledgling run of Coho salmon spawning in Clover Creek was all but wiped out this week, poisoned – probably – by urban pollution.

About 40 adult silvers died Wednesday and Thursday in Lakewood stream, which empties into Lake Steilacoom. The dead fish account for most of the spawning population in the creek, where volunteers have been working for years to restore salmon habitat.

At the same time, another 40 fish, including juvenile Coho, steelhead and cutthroat trout, turned belly up in Chambers Creek below the lake.

Storm water runoff, tainted by toxic residue from roads and urban development, is the prime suspect, said Washington Fisheries Department biologist Bill Graeber.

Paul Russell, of the Clover Creek Council, concurs.

He watched the fish, which appeared healthy and vigorous when they moved up into the stream Wednesday, begin to falter and start swimming sideways by late afternoon.

"I could tell they were in trouble," Russell said. "Thursday morning when I came down here, there wasn't a one that was alive."

The creek had been dry for several weeks until runoff from heavy rains Wednesday and Thursday sent water gushing in from hundreds of storm drains across the watershed.

"The fish were up in the lake, waiting for water," Russell said. But when the water finally came and the salmon ventured into the stream to spawn, they were migrating in little more than undiluted runoff.

"There's just about every known crud coming off the roads," said Darrell Mills, manager of the state's Garrison Springs Hatchery in Steilacoom. "All the oil and antifreeze and stuff like that washes right into the creek."

Biologists and spill experts from several state and local agencies waded into the creek today to collect water and slices of the scaly victims. The samples will all be analyzed, but the cause will probably never be pinpointed.

"The majority of times, we never find the answer," said Jim Oberlander of the Department of Ecology's spill response team.

Chemicals from a toxic spill somewhere in the Clover Creek watershed might have been siphoned into the storm drain, or the runoff might have been more potent than usual because the rain was the first in several weeks, biologists speculate.

Or the fish may have succumbed to something else altogether.

"We just don't know what the cause was," said Ken Canfield, head of surface water management for Tacoma.

Fish advocates and residents who have nurtured the Coho run were angry and frustrated.

"What we've been doing is using our creeks as cesspools," said Dan Schluter of Trout Unlimited.

"The integrity of each of these little streams and each of these runs is important to the entire Coho population."

Members and volunteers for the Clover Creek Council have built fish ladders and planted streamside vegetation to make the stream more hospitable to salmon, which once spawned there in profusion. Local school children tend vats of salmon eggs and plant thousands of fry each year, in the hope a few individuals will make it back to the creek.

"These guys have survived the whole gantlet," said Trout Unlimited member Bob Miller, pointing out the pale, floating corpses clustered near the shore. "Then we come up here and kill them with this damn pollution."

Pierce County is working to reduce the amount of toxic chemicals swept into runoff, Canfield said. Many businesses will soon be required to treat their runoff, and the county is planting natural grass buffers and installing oil-water separators in some drains.

And the Washington Department of Ecology is paying for a study of all the pollutants running into Lake Steilacoom, said state water quality inspector Loree Randall.

"Even if it turns out that we're unable to find anything this time," she said, "it's not like those areas aren't going to be monitored."

APPENDIX E

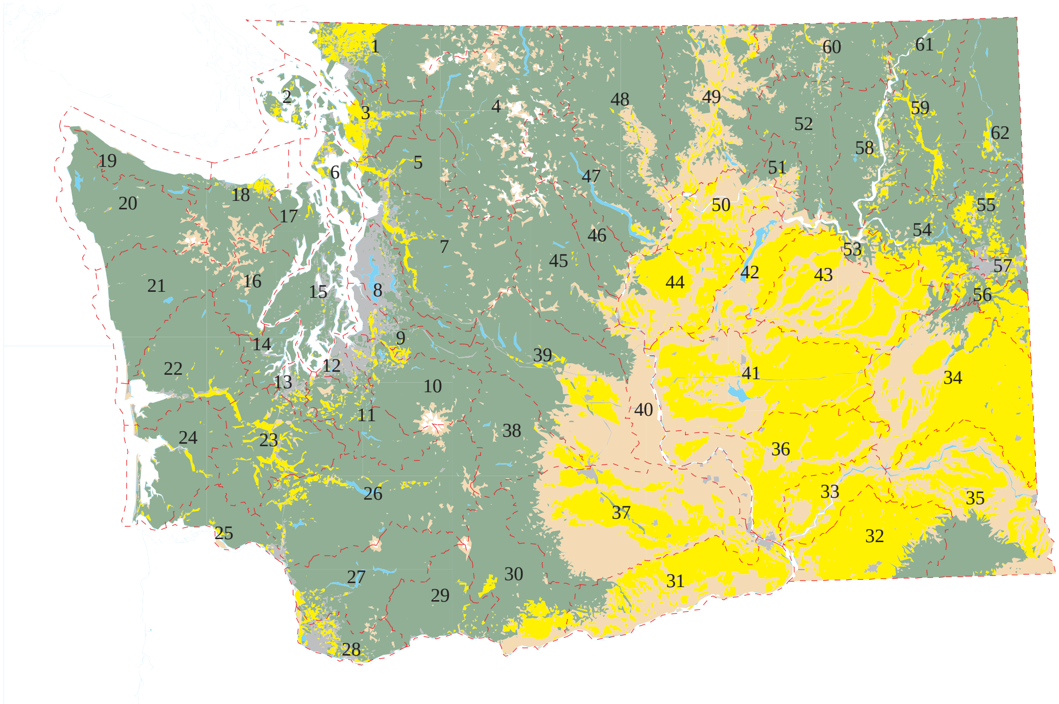
WRIA 12 Elevation Model

WRIA 12 Land Use/Land Cover Map

Chambers/Clover Water Resource Inventory Area (WRIA) #12 Elevation Model

Wa. Dept. of Ecology, GIS Technical Services 07/25/02

10-meter resolution DEM, topo12



Water Resource Inventory Areas and Land Use/Land Cover Legend

Agriculture
Forest (evergreen)
Forest (mixed)
Transitional
Shrub
Grass (herbaceous)
Barren
Urban (commercial)
Urban (residential)
Glacier
Water

Federal/State Highway
Secondary Route
Rivers/Streams
WRIA Boundary
County/State Boundary

Note: Not all colors/types represented in image above

Land Cover Source:
Land Use/Land Cover - USGS 2000 National Land Cover Data
Multi resolution Land Characterization (MRLC), 30 meter
resolution Landsat TM data, 1986 - 1996.
http://landcover.usgs.gov/nationallandcover.html

Other data:
WDNR/ECOLOGY - Water Resource Inventory Areas 1999 1:24K (WRIA)
WDFW/ECOLOGY - Hydrography 1998 1:100k (HYDROFW)
WDOT - Transportation 2000 1:24k (SR24K,ROADS24K)

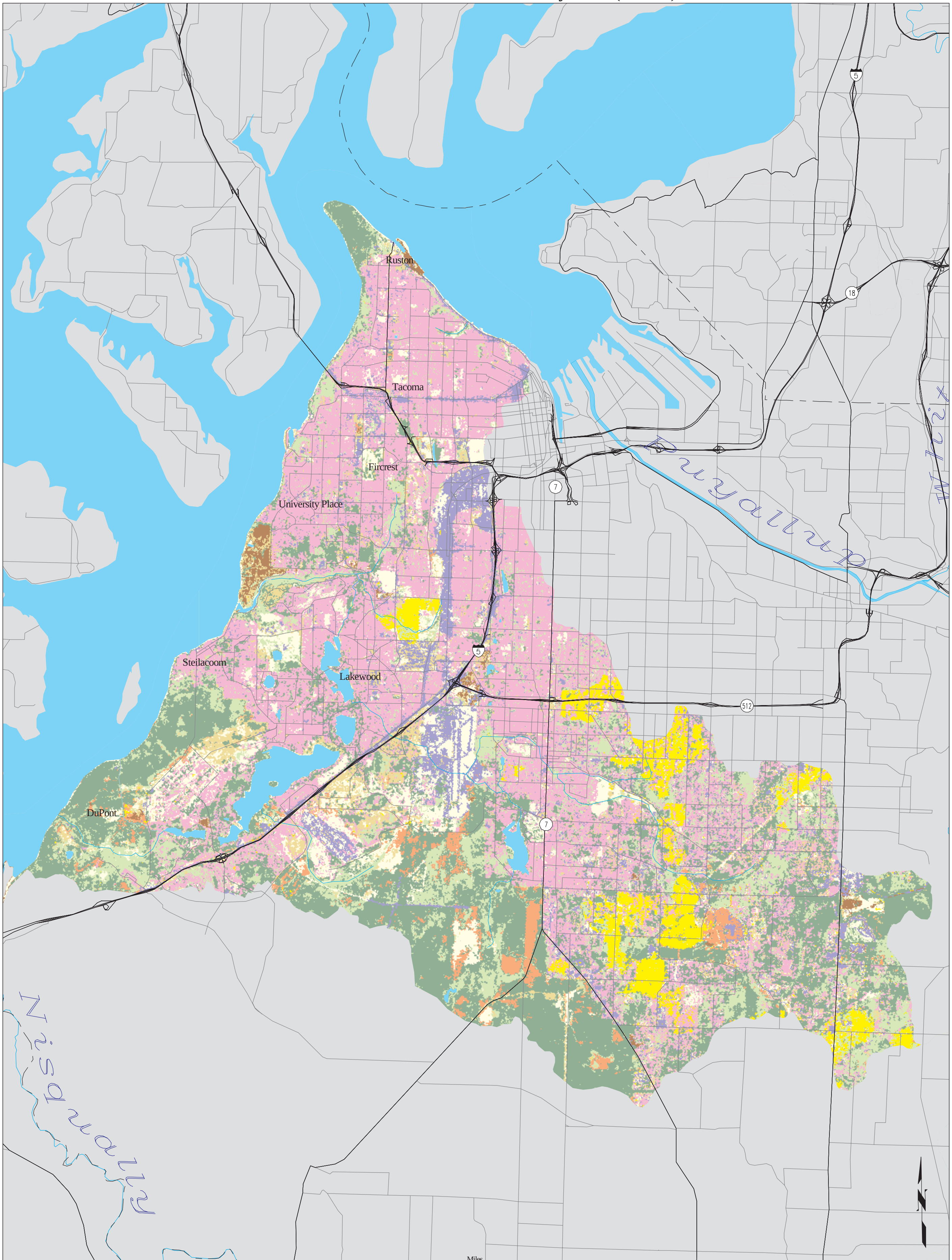
WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

GIS Technical Services

02/26/02

WRIA 12 Land Use/Land Cover Map

Chambers/Clover Water Resource Inventory Area (WRIA) #12

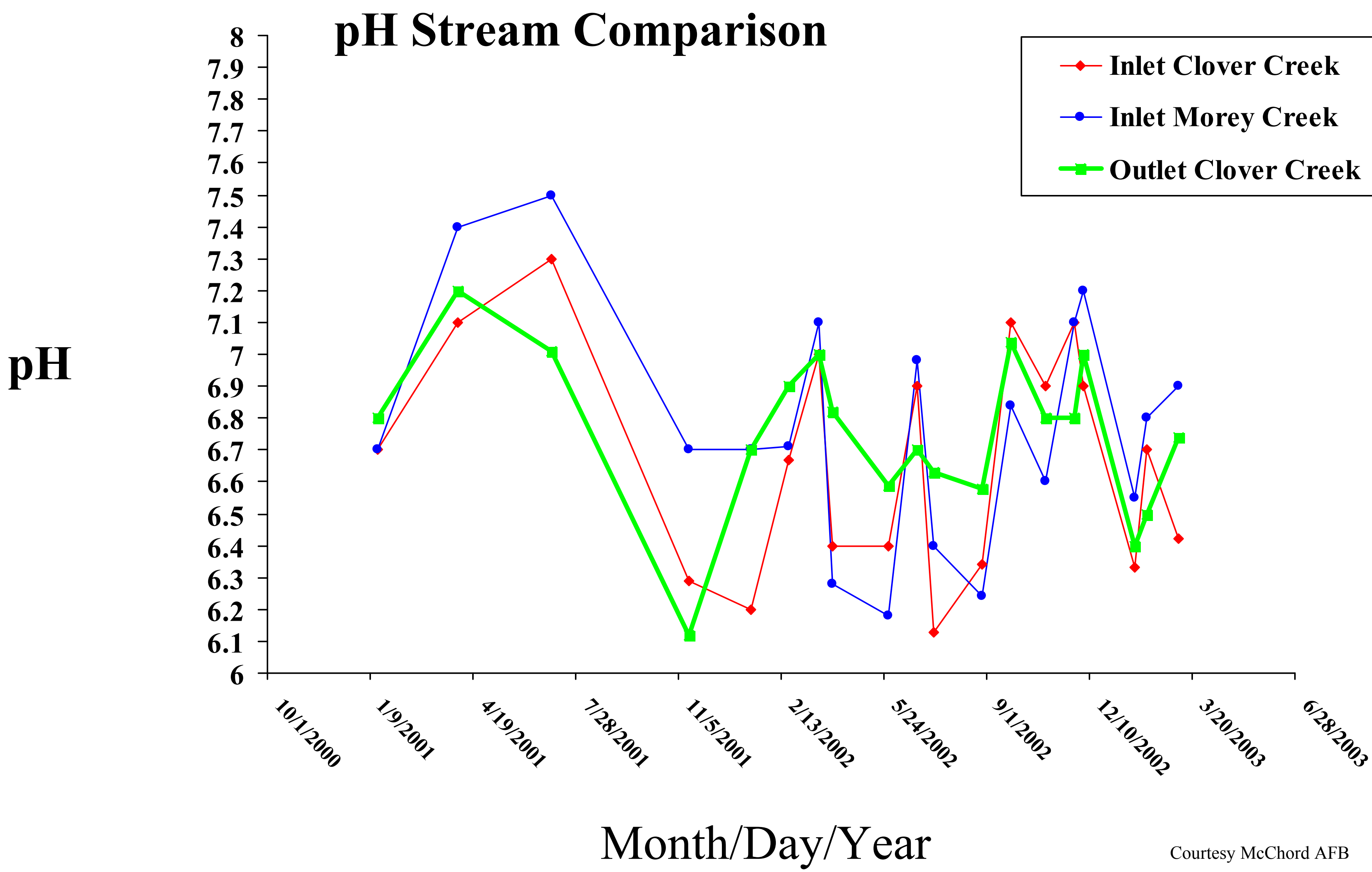


Wa. Dept. of Ecology, GIS Technical Services 02/26/02

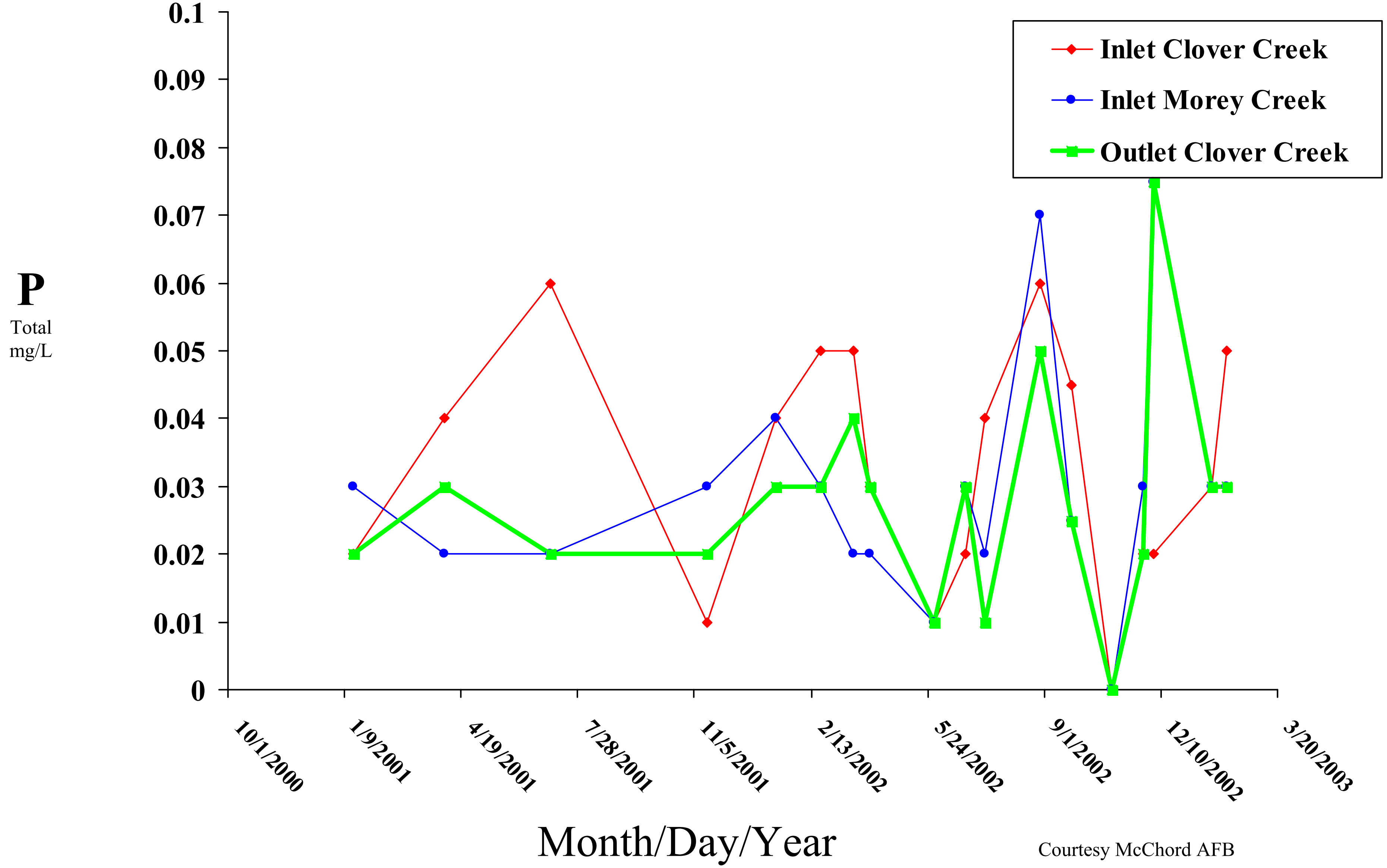
Land Use/Land Cover lc12a

APPENDIX F

McCord AFB Charts of the Results of pH and Phosphorus Testing (2000 - 2003)


pH Stream Comparison
Inlet Clover Creek
Inlet Morey Creek
Outlet Clover Creek
pH
8
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7
6.9
6.8
6.7
6.6
6.5
6.4
6.3
6.2
6.1
6
10/1/2000
1/9/2001
4/19/2001
7/28/2001
11/5/2001
2/13/2002
5/24/2002
9/1/2002
12/10/2002
3/20/2003
6/28/2003
Month/Day/Year
Courtesy McChord AFB

Phosphorus in Surface Water (Modified)



Courtesy McChord AFB